THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Radio Spectrum Management in the European Union

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Abstract

This thesis work was conducted to explain how the radio spectrum is managed in the European Union (EU). The radio spectrum is the natural resource which makes modern wireless communication possible. Like other natural resources, the radio spectrum is managed by nations within their national territories. Although nations have permanent sovereignty over the radio spectrum, the countries member of the EU share with the EU institutions the responsibility to manage such resource. The fact that EU and national institutions co-manage the radio spectrum generates a tension between the stances of the EU and the EU member states with respect to how the radio spectrum should be used. On the one hand, the EU aims to develop a common approach to radio spectrum use by promoting centralisation of decisional power to the EU level. On the other hand, the EU member states oppose major limitations to national sovereignty over the radio spectrum, protecting their right to dispose of their national resources in accordance with their national interests. A coordinated approach to radio spectrum management at EU level has only recently been set up. For this reason, the extent to which roles and responsibilities are divided between the EU and the EU member states has not been thoroughly investigated.

This thesis concentrated on identifying entities which manage the spectrum resource in the EU and the mechanisms used by such entities. To address these two aspects, qualitative data on EU legislative interventions in radio spectrum policy was collected to show variation over time of distribution of decisional power between the EU and the EU member states. Moreover, the phenomenon of business lobbying was studied to understand the importance of influencing EU legislation for commercial radio spectrum users. The external representation of the EU in international negotiations on radio spectrum use was also analysed to show the dual nature of the EU, being simultaneously one unitary entity and a conglomeration of several sovereign states. In addition, the use of soft power by the EU to develop a common approach to radio spectrum was discussed, in particular with respect to radio spectrum sharing.

This research work showed that radio spectrum management is a very complex matter where there is no clear-cut division of responsibilities between the EU and the EU member states. Over time, the EU has developed a more systematic approach to radio spectrum management, designing specific mechanisms to promote EU-coordinated radio spectrum use. At the same time, there are certain areas of radio spectrum management where the EU plays a mere advisory and coordinating role, while relevant decisions are taken at national level. Technological progress has often motivated the EU to put pressure on the EU member states for further integration. In this regard, it can be expected that future technological developments will drive further changes in the distribution of responsibilities between the two levels of governance.

Keywords: business lobbying; European Union; EU integration; international relations; radio spectrum management.

List of appended research papers

This thesis consists of a collection of five research papers, preceded by an introducing document entitled "Radio Spectrum Management in the European Union." In the introducing document, the general research approach adopted to develop this thesis is illustrated. The five appended papers are listed below, following the order of publication. They are referred to by Roman numerals in the text.

The author of this thesis is the sole author of Paper I, Paper II, Paper III, and Paper IV. Paper V is co-authored with Associate Professor Fernando Beltran from the University of Auckland Business School. The authors of Paper V were equally involved in defining the purpose, collecting and analysing data, and drawing conclusions. The author of this thesis was also responsible for the overall structure and most of the writing of Paper V.

Paper I — Massaro, M. (2017) Next generation of radio spectrum management: Licensed shared access for 5G, *Telecommunications Policy,* 41(5-6): 422–433. Special issue "Optimising Spectrum" edited by M. Cave and J. Given. DOI: https://doi.org/10.1016/j.telpol.2017.04.003.

Earlier versions of this paper were presented at the 26th European Regional Conference of the International Telecommunications Society (ITS), 27-27 June 2015, San Lorenzo de El Escorial, Spain, and at the 2015 ITS Regional Conference, 27-28 October 2015, Los Angeles, California, USA.

Paper II — Massaro, M. (2018) Radio spectrum regulation as a matter of international affairs: discussing the effectiveness of the European Union at World Radiocommunication Conferences, *Digital Policy, Regulation and Governance,* 20(5): 373–398. DOI: https://doi.org/10.1108/DPRG-09-2017-0049.

This paper is a revised version of a conference paper which was awarded the 2017 **Yale M. Braunstein Student Prize Award** from the Pacific Telecommunications Council (PTC). It was presented at the 39th PTC Annual Conference, 15-18 January 2017, Honolulu, Hawaii, USA.

Paper III — Massaro, M. (2019) Between integration and protection of national sovereignty in the European Union's radio spectrum policy: uncovering potential research avenues, *Journal of Information Policy,* 9: 158–197. DOI: https://doi.org/10.5325/jinfopoli.9.2019.0158.

This paper is a revised version of a conference paper which was selected as recipient of the 2018 **PTC Young Scholar Programme** and was presented at the 40th PTC Annual Conference, 21-24 January 2018, Honolulu, Hawaii, USA. Earlier versions of this paper were presented at: the 20th ITS Biennial Conference, 30 November-3 December 2014, Rio de Janeiro, Brazil; the Annual Scientific Seminar of the Florence School of Regulation, 27-28 March 2015, Florence, Italy; and the Workshop in European Legal Studies of the Swedish Network for European Legal Studies, 21-22 August 2018, Stockholm, Sweden. Financial support to develop this paper was received from the Forskraftstiftelsen Theodor Adelswärds minne, http://www.fstam.se.

Paper IV — Massaro, M. (2019) Is business lobbying in the European Union context-dependent? Evidence from the policy field of radio spectrum, *Telecommunications Policy,* in

press. Special issue based on selected papers presented at the 22nd ITS Biennial Conference, 24-27 June 2018, Seoul, South Korea, edited by S. Kim, C. Nam, and M. Ryu, DOI: https://doi.org/10.1016/j.telpol.2019.101827.

This paper is a revised version of a conference paper which was awarded the **third best student prize award** at the 22nd ITS Biennial Conference, 24-27 June 2018, Seoul, South Korea. Financial support to develop this paper was received from the Forskraftstiftelsen Theodor Adelswärds minne, http://www.fstam.se.

Paper V Massaro, M. and Beltrán, F. (2019) Will 5G lead to more spectrum sharing? Discussing recent developments of the LSA and the CBRS spectrum sharing frameworks. Under a second round of revision for publication in *Telecommunications Policy.*

An earlier version of this paper was presented at the 29th ITS European Regional Conference, 1-4 August 2018, Trento, Italy.

Doctoral thesis examination

Time and Place	6 December 2019 at 13:15 Room Vasa A, Vasa Building Chalmers University of Technology Vera Sandbergs Allé 8 412 96 Göteborg, Sweden
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1 October 2019
Maria Massaro

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List of abbreviations

5G	Fifth Generation
AGCOM	Italian Communications Regulatory Authority
BEREC	Body of European Regulators for Electronic Communications
CBRS	Citizens Broadband Radio Services
CEPT	European Conference of Postal and Telecommunications Administrations
CJEU	Court of Justice of the European Union
CPM	Conference Preparatory Meeting
CUS	Collective Use of Spectrum
ECC	Electronic Communications Committee
ECP	European Common Proposal
eLSA	Evolved Licensed Shared Access
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission
FSR	Florence School of Regulation
Hz	Hertz
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IRG	Independent Regulators Group
ITS	International Telecommunications Society
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radiocommunication Sector
ITU-D	International Telecommunication Union – Development Sector
LSA	Licensed Shared Access
NRA	National Regulatory Authority
NTIA	National Telecommunications and Information Administration
OFCOM	Office of Communications
OLP	Ordinary Legislative Procedure
PTC	Pacific Telecommunications Council
PTS	Swedish Post and Telecom Authority
RR	Radio Regulations
RSC	Radio Spectrum Committee

RSPG	Radio Spectrum Policy Group
SAS	Spectrum Access System
SNELS	Swedish Network for European Legal Studies
SNES	Swedish Network for European Studies in Political Science
TEU	Treaty on European Union
TFEU	Treaty on the Functioning of the European Union
TPRC	Telecommunications Policy Research Conference
UHF	Ultra High Frequency
US	United States
WRC	World Radiocommunication Conference

Radio spectrum management in the European Union

This introducing document provides the reader with a general overview of this research work. In particular, this introducing document is divided in six sections. Section 1 explains what the radio spectrum is and how it is managed. Moreover, it outlines purpose and research questions. Section 2 introduces the literatures this research work draws upon in order to answer the research questions. Section 3 is dedicated to the philosophical underpinnings of this thesis work, concerned with ontology, epistemology and methodology. In addition, details on methods of data collection and analysis are provided. The logical reasoning followed to draw conclusions from the data is also outlined. Section 4 provides a summary of the five appended papers. In section 5, the conclusions drawn in the five papers are discussed with respect to the overall research purpose. Finally, Section 6 concludes with recommendations for future research.

1 Why the radio spectrum and why the European Union

The first chapter of this introducing document is necessary for the reader to understand the importance of conducting research on radio spectrum management in the EU. In sub-section 1.1 the reader will learn about the physical characteristics of the radio spectrum, which make it an essential natural resource for the modern society, in particular for the provision of wireless communications services. By reading sub-section 1.2, the reader will understand that managing the radio spectrum is a demanding task, which requires the involvement of various national and supranational institutions. Finally, sub-section 1.3 explains to the reader that the EU adds to the institutional framework for radio spectrum a further layer of complexity, the EU being neither a national nor a supranational institution but presenting both national and supranational elements. The fact that the EU is a sui generis organisation provides the rationale for the main purpose of this thesis: explaining how the radio spectrum is managed in the EU.

1.1 The radio spectrum is a natural phenomenon

The radio spectrum is a specific type of electromagnetic radiation. As shown in Figure 1, electromagnetic radiation is a form of oscillating electric and magnetic fields capable of propagating thorough solid materials, air, and the vacuum of space, in a wave-like pattern, without the support of a physical medium (Herter Jr., 1985; ITU, 2016; NASA, 2019). Electromagnetic radiation is conventionally classified into categories, on the basis of their propagation properties. These categories are: gamma-ray, X-ray, ultraviolet, visible, infrared, microwave, and radio (National Imagery and Mapping Agency, 1995). Each type of electromagnetic radiation serves specific purposes. For instance, microwaves enable microwave ovens to warm up food. X-rays are used by the airport security to check what items passengers carry in their travel bags. Individuals use radio every time they access internet on mobile phones.

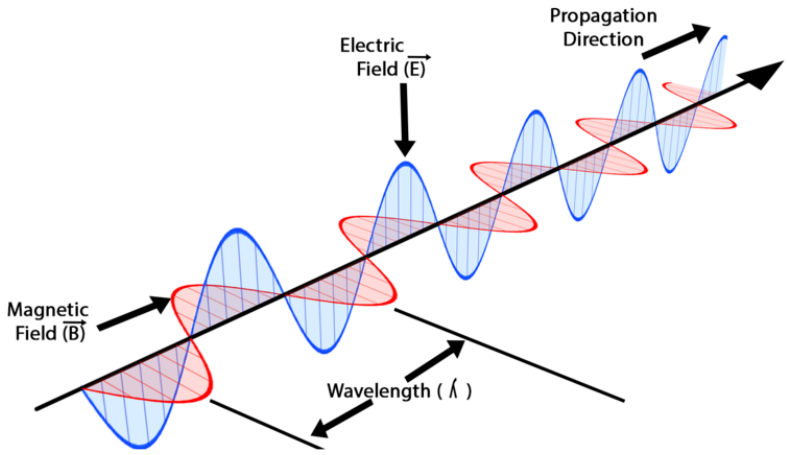

Figure 1. The electromagnetic wave
Source: Wikipedia (2018)

Propagation properties are usually described in terms of wavelength and frequency (Herter Jr., 1985). The wavelength is the distance travelled by an electromagnetic wave during the time of one cycle and it is measured in meters. One cycle is a complete sequence of values, as from crest to crest. The frequency indicates the number of crests which pass a given point in one second or the number of cycles that occur in one second, and it is expressed in Hertz (Hz). Wavelength and frequency are inversely proportional, which means that higher frequencies correspond to shorter wavelengths (Serway and Jewett, 2004). The radio spectrum is characterised by the longest wavelength (and the lowest frequency) in the electromagnetic spectrum, which makes it valuable for long distance communication.

The radio spectrum is generally described in terms of frequency. In particular, the radio spectrum is conventionally divided into nine frequency bands, as shown in Table 1. Although frequency is measured in Hz, as a matter of practicality, multiples of Hz are commonly used, such as kilohertz (1 kHz = 10^3 Hz); megahertz (1 MHz = 10^6 Hz); and gigahertz (1 GHz = 10^9 Hz). The frequency range of radio waves is comprised between 3 kHz and 3000 GHz.

Band Name	**Symbols**	**Frequency range**
Very low frequency	VLF	3 to 30 kHz
Low frequency	LF	30 to 300 kHz
Medium frequency	MF	300 to 3000 kHz
High frequency	HF	3 to 30 MHz
Very high frequency	VHF	30 to 300 MHz
Ultra high frequency	UHF	300 to 3000 MHz
Super high frequency	SHF	3 to 30 GHz
Extremely high frequency	EHF	30 to 300 GHz
Tremendously high frequency*	THF	300 to 3000 GHz

Table 1. The nine frequency bands of the radio spectrum
Source: ITU (2016); *ITU-R (2017)

Radio waves with higher frequencies reach shorter distances, carrying greater amount of information. Inversely, radio waves with lower frequencies travel longer distances. However, they have lower information-carrying capacity (NASA, 2019). Because of the desirable combination of propagation properties and information-carrying capacity, the Ultra High Frequency (UHF) band is considered

the “sweet spot” for many applications, including mobile internet services and terrestrial television broadcasting (CEPT, 2013).

1.1.1 The radio spectrum is a natural resource

The radio spectrum is one of the most precious natural resources for the modern society (Herter Jr, 1985; Levin, 2011; Cave and Webb, 2015). It serves as an essential asset for the provision of a wide variety of public and commercial services which are essential for personal, industrial, scientific, medical and cultural purposes (Cave and Webb, 2015; ITU and infoDev, 2007). For the scope of this thesis, natural resources are intended as the materials that exist in the natural environment of Earth and the space around it. They are both scarce and economically useful as inputs for the production of goods and the provision of services, or as direct source of utility for consumers (World Trade Organization, 2010). The radio spectrum has no economic value per se. Its value depends on the types of services for which it is a key input (ITU and infoDev, 2007).

The radio spectrum can be compared to other natural resources. Like land, the radio spectrum is heterogeneous in the sense that it can be used for different purposes. In fact, radio waves with varying frequencies and wavelengths allow for the provision of different types of services. The radio spectrum is also non-depletable. In fact, it does not run out because of its use. On the contrary, it is always in infinite abundance, except for the portion that is used. When that portion of the radio spectrum is not in use anymore, it is instantly renewable, and can be used for other purposes (Herter Jr, 1985). Soils or forests are also renewable but frequently at a price. In addition, the radio spectrum is a degradable resource, like land and water. The radio spectrum is polluted when harmful interference prevents the radio spectrum from being used for the provision of services (Herter Jr, 1985). In fact, the radio spectrum is subject to congestion: given present technology, access to the same or adjoining radio frequency bands by different radio spectrum users, at the same time and in the same location, might cause harmful interference, which can reduce or nullify the availability of the radio spectrum for valuable uses (Rosston and Steinberg, 1997; Cave, 2002; ITU and infoDev, 2007). Another characteristic of the radio spectrum is that it cannot be stored for later use, as it is commonly done with oil (ITU and infoDev, 2007). At the same time, it can be traded, by means of property rights systems, as it occurs for oil and gas (Coase, 1959; Hazlett et al., 2011). Trading the radio spectrum is important to reconcile demand and supply. A summary of the basic properties of the radio spectrum is provided in Table 2.

Property	**Explanation**
Heterogenous	The radio spectrum serves different purposes
Non-depletable (renewable)	The radio spectrum does not run out because of its use
Degradable	The radio spectrum is subject to pollution (interference)
Storing is not possible	The radio spectrum cannot be stored for later use
Tradable	Radio spectrum usage rights can be traded

Table 2. Basic properties of the radio spectrum

Although the importance of the radio spectrum (and of the services it enables) may seem less obvious, compared to other natural resources, such as land and oil, its impact on society is far-reaching. In particular, the radio spectrum is that portion of the electromagnetic spectrum which makes modern wireless communication possible. Wireless communication refers to the transfer of information between points without an electrical conductor. The term “modern” suggests that forms of wireless communication had already been developed before the radio spectrum started to be used. A short historical overview of communication systems, which preceded the discovery of the radio spectrum,

is provided in the next sub-section. After a short journey back through history, the reader will find it easier to understand the essential role that the radio spectrum plays in the modern world.

1.1.2 Brief historical overview of communication systems

During the pre-industrial age, various types of "rudimentary" wireless communication systems were in place, such as smoke signals, torch signals, drums, flashing mirrors, and flags. Observation points were located along roads to capture signals and advanced sets of signal combinations allowed for complex messages to be conveyed (Fouchard, 2016). The main issue with these types of communication mechanisms was that they were mostly limited to line-of-sight-distances. In addition, they were dependent upon weather conditions (Goldsmith, 2005). Up until the 1850s, long-distance communication was made possible thanks to physical means of information transportation, such as horses, pigeons and vessels (Fouchard, 2016). Information travelled across states and oceans. However, large timespans generally separated dispatch and reception of messages (Granatstein, 2012).

In the early 19th century, the invention of the electric telegraph was revolutionary in the context of long-distance communication. Thanks to a dense net of dedicated electric wires, the electric telegraph enabled almost instantaneous message transmission across states and continents (Granatstein, 2012). The inventor of the electric telegraph, Samuel Morse, also developed a code to transmit complex messages via the electric telegraph. Such code was based on various combinations of dots and dashes to represent the letters of the English alphabet (Gokhale, 2005). Although it worked well, the electric telegraph was soon overtaken by the telephone towards the end of the 19th century. Similar to the electric telegraph, the telephone was also an electric-based communication system. The main difference between the telegraph and the telephone was that while the former supported the transmission of written messages with the use of the Morse code, the telephone enabled instantaneous transmission of human voice, without the need to use a specific code of communication (Gokhale, 2005). Notwithstanding the importance of these communication systems for long-distance instantaneous communication, the issue of how to communicate with people in motion, for instance on ships, still persisted (Granatstein, 2012).

In the early 20th century, the invention of the wireless telegraph made possible not only long-distance and instantaneous communication, but also communication with mobile receivers (Belrose, 1995). The wireless telegraph freed communication from the physical constraints represented by wires which were required for both the electric telegraph and the telephone. In 1901, Guglielmo Marconi, widely considered the inventor of the wireless telegraph, successfully transmitted the Morse-code signal for the letter "s" from Poldhu in Cornwall, England, to Newfoundland, in Canada, over the air (Granatstein, 2012; The Engineering and Technology History Wiki, 2019). The invention of the wireless telegraph was made possible thanks to the contribution of various scientists to the development of electromagnetic theory during the 19th century (Schwab and Fischer, 1998). Up until the end of the 18th century, electricity and magnetism were considered two independent phenomena. Therefore, they were subject to distinct investigations by many scientists (Schwab and Fischer, 1998). Only in 1820, Hans Christian Ørsted found a connection between magnetism and electric currents, which was then analysed and developed by André-Marie Ampère. In 1831, Michael Faraday discovered the electromagnetic induction phenomenon, proving that magnetic fields can produce electric current (Smith, 1997). In 1864, James Clerk Maxwell mathematically explained the existence of electromagnetic waves. In 1887, Heinrich Rudolf Hertz applied Maxwell's work to conduct a series of experiments whereby he produced radio waves, proving the foundation of Maxwell's theory (Sengupta and Sarkar, 2003). Thanks to the pivotal contributions of Maxwell and

Hertz, coupled with the development of electronics, Guglielmo Marconi invented the wireless telegraph, proving the feasibility of long-distance instantaneous communication using the radio spectrum as vehicle. With the wireless telegraph, the era of modern wireless communication has begun (Falciasecca and Valotti, 2009; Herter Jr., 1985).

1.2 Radio spectrum management: allocation and assignment

Generally speaking, countries have permanent sovereignty over natural resources geographically located within their national boundaries (Barral, 2016; United Nations, 1962). This principle applies to the radio spectrum as well. Having complete sovereignty can be intended as the right of a country to dispose of the radio spectrum within its territory in accordance with its respective national interests (Horvitz, 2008). In the EU member states, the duty to manage the radio spectrum is generally carried out by an independent agency, generally named National Regulatory Authority (NRA), with the support of specific government ministries in some countries (Cave and Webb, 2015).

Managing the radio spectrum usually entails two major activities, called allocation and assignment. An allocation is the outcome of a binding decision which associates a frequency band to one or more specific services. In other words, a frequency band is allocated when a decision is taken on the services that can be provided by using that specific frequency band and under which conditions. An assignment is the outcome of a binding decision which associates a frequency band, allocated to certain services, to a limited number of service providers. In other words, a frequency band is assigned when service providers are granted national or sub-national authorisations to deliver their services by using that frequency band, under specific conditions (ITU, 2016). Service providers are granted individual authorisations, also called licenses, by participating in a comparative or competitive assignment procedure. Markets for radio spectrum rights of use have also been established to allow for a change of ownership by secondary trading (ITU and infoDev, 2007). The assignment of authorisations does not regard all radio spectrum bands. Some bands are used under a licence-exempt regime, which allows various users to provide services without holding a licence (Parliament and Council, 2009).

While decisions on assignments are taken nationally, allocations usually include some forms of cooperation between countries. In particular, countries cooperate thorough the framework offered by the International Telecommunication Union (ITU), a specialised agency of the United Nations. More specifically, the Radiocommunication sector of the ITU (ITU-R) is responsible for the management of the international regulatory framework for radio spectrum and the development of radiocommunication standards. Countries collectively decide on radio spectrum allocations for a number of purposes. In particular, spectrum harmonisation is a key objective of the country members of the ITU (ITU-D, 2015; Ofcom, 2018). Frequencies are harmonised when they are allocated to the same services at international or supranational levels. Nevertheless, the long-standing debate on the merits and evils of harmonisation in radio spectrum management is unresolved. On the one hand, harmonisation is desirable because it facilitates spectrum management and planning, as well as cross-country coordination, reducing the risk of cross-border interference. In addition, harmonisation is advantageous for equipment and device manufacturers, which can benefit from economies of scale. Spectrum harmonisation leads to lower equipment costs, expanded equipment availability and increased interoperability (ITU-R, 2015; Mazar, 2016). On the other hand, downsides connected to harmonisation include potential sub-optimal use of the spectrum resource in certain countries. This can happen when providers of the service for which the spectrum is harmonised do not demand additional spectrum. As a result, the spectrum is left unused or partially used. In these circumstances, spectrum may be better used by services which fulfil national needs (RSPG, 2016). Also, the

innovation process may be negatively affected. Harmonisation would slow down the introduction of more advanced technologies and services which require a flexible environment to emerge (Pogorel, 2007).

Every three or four years, the ITU-R holds World Radiocommunication Conferences (WRCs), where ITU member states take decisions in the matter of radio spectrum allocation. The ITU counts 193 member states, 700 sector members and associates, which include NRAs, the EU, and various entities from the private sector, and more than 100 academic members, such as universities and research institutes. Delegations of national governments take part in the decision-making process for radio spectrum allocation, while sector members, associates, and academia can attend WRCs as observers. They are also involved during the preparatory process to WRCs in various ways, for instance in carrying out studies to evaluate the risk of harmful interference due to the introduction of a new type of service in a frequency band.

At WRCs, a specific set of predefined issues is discussed. Such issues are included in the WRC agenda and sub-divided into agenda items. The agenda is decided upon at the previous WRC and finalized by the ITU Council, which is a governing body of the ITU. The so-called Conference Preparatory Meeting (CPM) is held to address topics on the agenda. Among other things, study groups are mandated to conduct regulatory, technical, operational and procedural studies related to the different agenda items. A summary of each agenda item and related study results are included in the CPM report. CPMs are generally held twice between two WRCs and attended by national administrations, companies and other entities.

Each WRC concludes with the adoption of amendments to specific portions of the Radio Regulations (RR). The RR is the international treaty that regulates the allocation of radio spectrum frequency bands to the various services and sets out how countries should coordinate. In particular, the RR contains the international Table of Frequency Allocations were all frequency bands and allocated services are indicated (ITU, 2016). Decisions on band allocations are taken based on the CPM report and national and regional contributions. ITU member states are not required to comply with the content of the RR, as long as the use of the radio spectrum in their national territories does not cause cross-border interference (Clegg, 2012). Nevertheless, ITU member states generally consider it to be in their interests to comply with the RR, recognising the benefits of coordinated spectrum use (Manner, 2003).

In the RR, the globe is conventionally divided into three macro-regions, called ITU Region 1, Region 2 and Region 3. As illustrated in Figure 1, Region 1 includes Europe, Africa, the Middle East, Iraq, the former Soviet Union and Mongolia. Region 2 covers the Americas, Greenland and some of the eastern Pacific Islands; and Region 3 comprises most of the Asian countries, which were not part of the former Soviet Union, Iran, and most of Oceania (Cave and Webb, 2015).

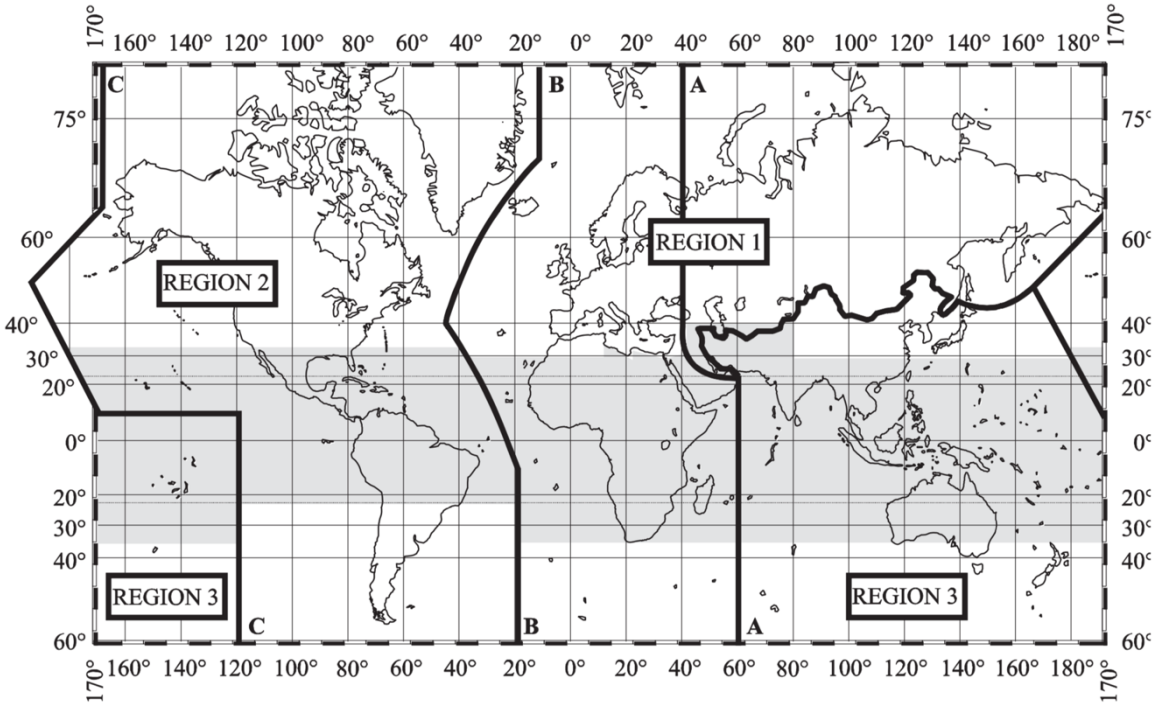

Figure 2. The ITU Regions
Source: ITU (2016)

Countries belonging to the same ITU Region have established regional organisations to create a forum for discussion and strengthen cooperation. In particular, countries in Region 1 are organised in four regional entities: the European Conference of Postal and Telecommunications Administrations (CEPT), the African Telecommunications Union, the Arab Spectrum Management Group, and the Regional Commonwealth in the Field of Communications. Countries in Region 2 are members of the Inter-American Telecommunication Commission. Countries in Region 3 belong to the Asia-Pacific Telecommunity. The EU member states are members of the CEPT. Currently, the CEPT counts forty-eight member countries, corresponding to almost the entire geographical area of Europe.

The overall aim of regional organisations is to promote cooperation between countries. On behalf of the countries they represent, each regional organisation is responsible for formulating regional proposals to review the RR at WRCs. Within the CEPT, a specialised Conference Preparatory Group is set up to prepare the so-called European Common proposals (ECPs) for WRCs. ECPs contain common proposals for amendments to the RR. They are adopted with the support of ten CEPT members and the opposition of not more than six CEPT members (CEPT, 2009). However, they are not binding. The ECPs, together with the other regional proposals, are used as starting points for negotiations at WRCs.

1.3 Radio spectrum in the EU: purpose and research questions

Radio spectrum management is generally considered a national responsibility. Countries around the world set rules to regulate radio spectrum use in their national territories and coordinate internationally to promote radio spectrum harmonisation. However, membership of the EU affects national sovereignty over the radio spectrum of the EU countries. The EU is a political and economic union of twenty-eight countries, which benefit from the privileges and bear the obligations that come with the EU membership. When joining the EU, countries agree on conferring certain decisional

powers to the EU, with consequent limitation of national sovereignty (EU, 2012). In particular, radio spectrum policy belongs to the category of policies where the EU and the EU member states share competence. Sharing competence means that both national and EU institutions have the right to legislate in a specific policy area, setting binding rules on how the radio spectrum should be used across the EU.

The fact that EU and national institutions co-manage, to some extent, the radio spectrum generates a tension between the stances of the EU and the EU member states with respect to how the radio spectrum should be managed and by whom. On the one hand, EU institutions aim to develop a common approach to radio spectrum management across the EU. This would entail centralisation of decisional power to the EU level to a certain extent. According to the EU, harmonisation of the rules governing radio spectrum is necessary for the well-functioning of the EU internal market for telecommunications, which, in turn, contributes to the EU's global competitiveness. On the other hand, the EU member states oppose major limitations to national sovereignty over the radio spectrum, it being considered a matter of exclusive national competence. National sovereignty would be restricted by allocating legislative power to a different level of decision-making. This tension between the EU and its member states is the leitmotiv of the EU integration process, a process started in the 1950s which continues to create dynamics for change in the roles and responsibilities of EU and national institutions.

Against this background, the purpose of this thesis was to explain how the radio spectrum is managed in the EU. In particular, this thesis concentrated on addressing the following research question: what entities manage the radio spectrum in the EU? The term entity is broadly used to indicate public bodies involved in radio spectrum management. An entity can be a political institution, an independent regulatory agency or an international organisation. EU decision-making is characterised by the central role of three political institutions, namely the European Commission (hereafter "Commission"); the European Parliament (hereafter "Parliament") and the Council of the EU (hereafter "Council"). These institutions are unique in the way they share legislative and executive powers. The Commission is in charge of promoting the interests of the EU as a whole. It is the only EU institution who has the right to formulate legislative proposals in the context of the ordinary legislative procedure (OLP), which is the standard procedure for adopting EU laws. It is also considered the executive arm of the EU. The Parliament and the Council share the legislative power to pass EU laws. The Parliament represents the citizens of the EU, while the Council gives voice to the national governments at EU level. In addition to the three main EU institutions, the EU is characterised by a variety of other institutions and bodies which have different powers and responsibilities depending on the policy field under consideration. Given the complex institutional nature of the EU, the question of which institutions and bodies manage the radio spectrum in the EU has no straightforward answer. On the contrary, it requires familiarity with the EU system.

The EU generally adopts laws to achieve policy goals. For this reason, examining the legislative process whereby EU laws are adopted is a first step towards understanding radio spectrum management in the EU. Due to the tension between transfer of decision-making power to EU institutions and protection of national sovereignty, the EU has also developed soft mechanisms to promote EU integration. These mechanisms encourage but do not oblige the EU member states to cooperate. In this regard, this thesis addressed the following research question: what mechanisms are used to manage the radio spectrum in the EU?

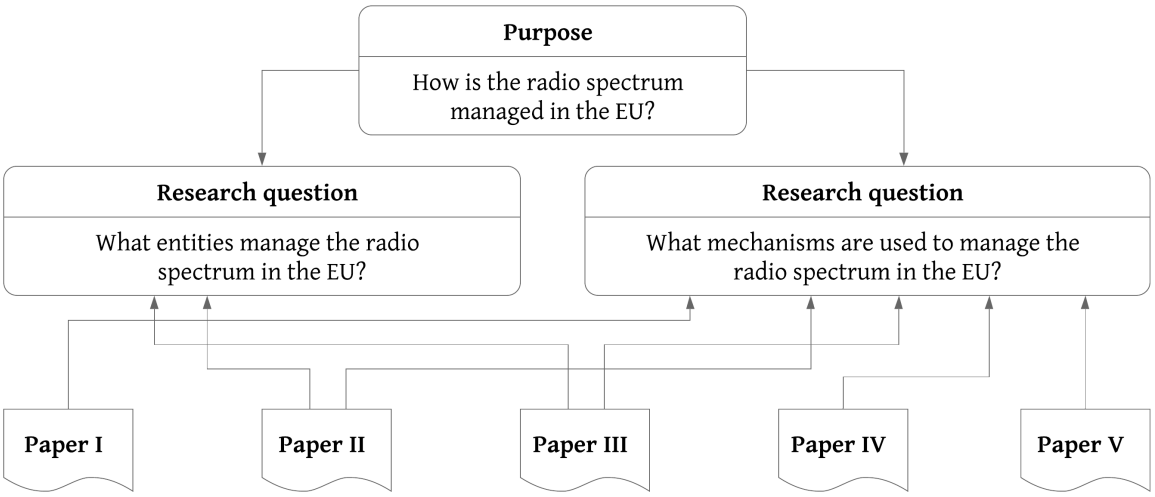

Figure 3. Contribution of the five appended papers to the research questions

As shown in Figure 3, the appended papers have contributed to addressing the two research questions to different extents. The first research question about the entities was mainly addressed in Paper II and Paper III, where the external representation of the EU at WRCs and the question of shared competence between the EU and the EU member states were respectively investigated. Paper I, Paper II, Paper III, Paper IV and Paper V contributed to answer the second research question about the mechanisms. In Paper II, Paper III and Paper IV, different types of mechanisms for the adoption of legally binding instruments were discussed. Paper I and Paper V focused on EU policy initiatives for the promotion of spectrum sharing with no legally binding effects for the EU member states.

The scope of investigation of this thesis was narrowed to radio spectrum management for commercial uses of the radio spectrum, in particular for mobile internet services. Recent developments concerning the mobile technology has put radio spectrum management under the spotlight. In particular, intense discussions are currently involving policy-makers, the industry and the academia to understand how to meet the spectrum demands of the upcoming fifth generation (5G) of mobile technology. 5G is expected to bring substantial economic and social benefits worldwide, supporting the digitalisation of several industries such as: transport, health, manufacturing, logistics, energy, media and entertainment. The EU aims to be at the forefront of 5G development (Commission, 2017a) in order to become leader of the digital economy, creating favourable conditions for EU companies and individuals to take advantage of the opportunities that digitalisation can offer (Commission, 2015). According to the Commission, creating a common approach to radio spectrum across the EU is necessary to strengthen EU competitiveness in the digital economy (Commission, 2013).

2 Understanding radio spectrum management in the EU

This thesis drew on different literatures to explain how the radio spectrum is managed in the EU. The need to develop a multi-perspective approach arose during the research process to analyse the complex nature of radio spectrum management. This complexity is due to the fact that although the radio spectrum is a matter of national sovereignty, it also requires countries to coordinate. The EU represents an additional element to be disentangled. The EU is an entity of dual nature, where supranational efforts to coordinate the use of radio spectrum across the EU coexist with the endeavour of the EU member states to protect their national sovereignty.

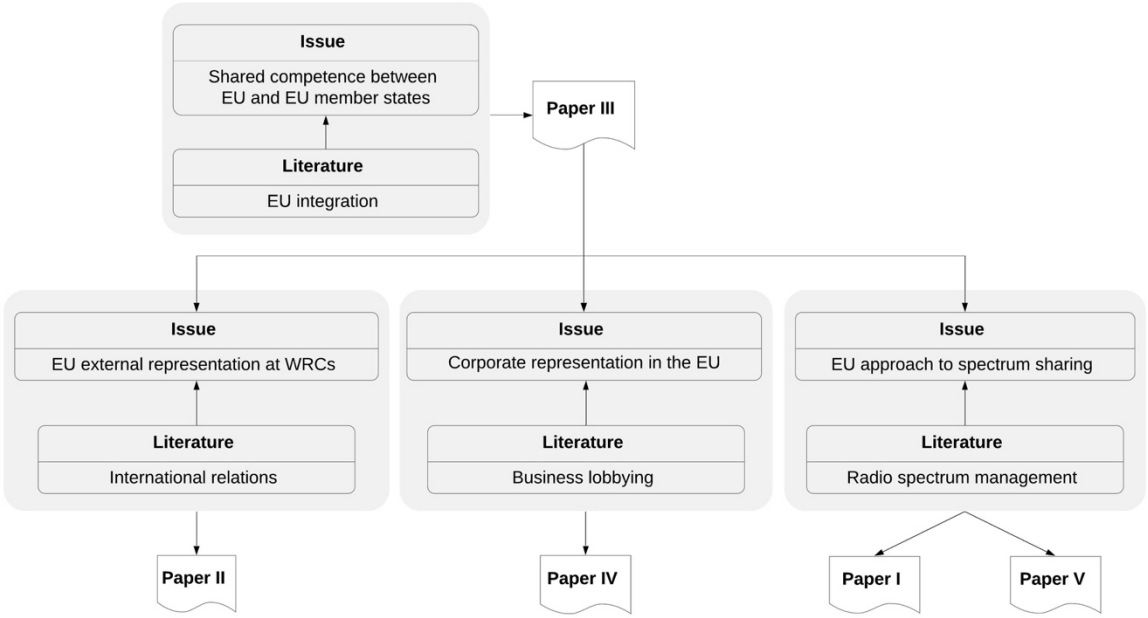

Figure 4. Map of the literatures used in the five appended papers

As shown in Figure 4, ideas were borrowed from four different literatures to develop the five appended papers. The research process started with the development of Paper III, which provided the foundation for the development of the other papers. The four literatures used were: EU integration, international relations, business lobbying, and radio spectrum management. EU integration, international relations and business lobbying literatures were employed respectively in Paper III, Paper II and Paper IV to understand political aspects of EU decision-making, including roles and responsibilities of EU institutions and their interaction with business interest representatives. In particular, literature on EU integration was used in Paper III to investigate the question of shared competence between the EU and the EU member states in radio spectrum policy. Literature on international relations was used in Paper II to investigate the external representation of the EU at WRCs. In Paper IV, concepts from the business lobbying literature were borrowed to understand how business lobbying takes place in the policy field of radio spectrum in the EU. Radio spectrum management literature was used in Paper I and V to explore approaches to radio spectrum sharing promoted by the EU. Each literature is presented in detail in the remaining parts of this section.

2.1 EU integration literature in Paper III

The development of this research work started with looking at EU decision-making from the perspective of EU integration literature. Since its origins in the 1950s, the process of EU integration has attracted increasing attention from scholars which have attempted to explain the formation and the functioning of the EU, as well as to foresee its future developments (Rosamond, 2000). These attempts resulted in various theories about the institutions and the mechanisms which contributed to the creation of such supranational institutional structure.

EU integration literature tries to explain the coexistence and evolution of intergovernmental and supranational elements of governance in the EU system (Pollack, 2001). Intergovernmental theories conceive EU integration as a process driven by the EU member states. According to these theories, the EU member states would voluntarily confer legislative power to the EU institutions only when empowering the EU institutions is a necessary step to satisfy their own national interests. Otherwise, intergovernmental routes are generally preferred (Hoffman, 1966; Pollack, 2005; Moga, 2009). According to supranational theories, the EU institutions would be able to independently drive further the process of EU integration, beyond the powers conferred upon them by the EU member states. Integration in certain policy areas would put pressure on the EU member states to extend the legislative power of the EU institutions to neighbouring policy areas.

In particular, EU integration literature was used in Paper III to understand how competence was distributed between EU and national institutions in radio spectrum policy. Based on the distribution of legislative power between the EU and the EU member states, policy areas can broadly be distinguished in three main categories. The first category includes policy areas where the EU has exclusive competence, which means that the EU has the sole power to legislate, whereas the EU member states retains no legislative power. The second category includes policy areas which are of exclusive domain of the EU member states. In these policy areas, the EU has the power to support, coordinate or supplement the actions of its member states. However, it cannot adopt legally binding acts which would require the EU member states to harmonise their laws. The third category includes policy areas of shared competence between the EU and the EU member states. Competence is shared when both the EU and the EU member states can legislate (EU, 2012).

The division of competence between the EU and its member states is grounded in the principle of EU law known as the principle of conferral, whereby the EU can exercise its legislative power within the limits of the competence voluntarily conferred upon it by the EU member states in the EU treaties, such as the Treaty on EU (TEU) and the Treaty on the functioning of the EU (TFEU) (EU, 2012). These treaties are binding international agreements, whereby the EU member states unanimously agreed on conferring the EU institutions the power to act, to different extents, in various policy areas. Any policy area not mentioned in the EU treaties remains in the exclusive domain of the EU member states (EU, 2012).

The matter of competence distribution has been a hot topic in EU research since the beginning of the EU integration process (Rosamond, 2000; Pollack, 2000; Henkel, 2002; Henke, 2006; Heidbreder, 2014). Particular attention has been devoted to the exercise of legislative power by the EU institutions in policy areas of shared competence, such as financial services and capital markets (Pelkmans, 2005; Dixon, 2014), labour markets (Pelkmans, 2006), agriculture (Grether, 2008), environment (Morgera et al., 2011), and education (Ploeg and Veugelers, 2008). The general aim of many studies on competence distribution was to investigate various "concerns about subsidiarity" (Pelkmans, 2005: 2). In policy areas of shared competence, the exercise of legislative power by the EU institutions is regulated by the general principle of EU law called the principle of subsidiarity (EU, 2012). This

principle aims to ensure that decision-making takes place at the most appropriate level of governance. In particular, applying the principle of subsidiarity entails that decisional power should rest with the lowest level of government, unless allocating decisional power at higher levels would translate into comparatively higher benefits (Føllesdal, 1998). According to the definition provided in the TEU, the EU can act only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the EU Member States.

Concerns about subsidiarity mainly regard its application. The formulation of the principle of subsidiarity in article 5 of the TEU suggests that potential EU and national measures to address a certain problem need to be compared before the EU can act. The EU needs to demonstrate that the EU member states, acting alone, cannot reach the desired objectives. Nevertheless, no indication is offered as to how the EU should conduct such comparative assessment (Henkel, 2002). This leaves large discretion to the EU as to how to argue in favour of actions at EU level. Similarly, the EU member states have mixed reactions with respect to the application of the principle of subsidiarity, sometimes criticizing too much intrusion of the EU in national affairs, sometimes calling for more centralisation of power at the EU level in specific policy areas (Gelauff et al., 2008).

In Paper III, these concerns on subsidiary are taken as the foundation of a discussion on the division of competence between the EU and the EU member states in the policy field of radio spectrum. In particular, Paper III shows the tension between the ambition of the EU to increase its competence and the opposition of the EU member states to further restrictions to their national sovereignty. This tension is shown while mapping all EU legislative proposals in radio spectrum policy over time, comprising those which were rejected by the EU member states represented in the Council and, therefore, failed to become EU laws.

2.2 International relations literature in Paper II

International relations literature was used in Paper II to investigate the participation of the EU in the work of the ITU. Paper III showed that the EU became gradually more engaged in international negotiations on radio spectrum management, in particular in the context of the ITU, as a result of the transfer of certain decisional power to the EU level. As countries are the only ITU members with the right to take decisions, it appeared relevant to understand how the EU engages in international activities.

International relations literature arose in the aftermath of the First World War to provide theoretical tools for analysing the nature of international politics (Burchill and Linklater, 2005). Over the years, the complexity of international relations has given rise to a proliferation of heterogeneous multidisciplinary theoretical approaches (Andreatta, 2011), which address, but are not limited to, historical, economic, and legal aspects of international relations (Jackson and Sørensen, 2016). For long time, the role of the EU in international negotiations was neglected by international relations literature, which assumed that external relations were specifically a national responsibility (Bretherton and Vogler, 2006). Furthermore, other dominant players in world politics have been struggling with recognising and accepting the EU as an international entity, due to limited understanding of its multi-level governance structure (Waele and Kuipers, 2013). In reality, the EU has often been acting as a global actor, promoting and supporting trade negotiations, military interventions, democracy, international development, climate change debates, and reforms of international financial institutions (Waele and Kuipers, 2013). As a result of the increasing participation of the EU in global politics, the academic world has grown a strong interest to research about the international role of the EU (Wunderlich and Bailey, 2011; Jørgensen et al., 2011).

International relations scholars began to approach the study of the EU since the idea of a "United Europe" arose in the 1950s (Milczarek, 2013). The EU became a very interesting subject of study for its unique nature, being more than an intergovernmental organisation, but less than a fully-fledged supranational state (Wessels, 1982). Studies were conducted on the participation of the EU in the work of various international organisations, such as the UN (Brantner and Gowan, 2009; Buonanno and Nugent, 2013); the North Atlantic Treaty Organization (Menon, 2011; Simon, 2012; Varwick and Koops, 2009; Buonanno and Nugent, 2013); the International Monetary Fund (Smaghi, 2009); the International Criminal Court (Groenleer and Schaik, 2007); and the World Trade Organization (Gehring et al., 2013). Shahin (2011) is one of the few authors which explore the role of the EU in the ITU.

According to Hill et al. (2017), the EU can be conceptualised in three different and complementary ways with respect to international relations. First, the EU can be seen as a global power, whose economic, political and military weight affects world politics. Second, the EU can be understood as a subsystem of international relations, where bilateral and multilateral relationships between the twenty-eight member countries of the EU take place. The third perspective brings together the previous two, to analyse the tension between the ambition of the EU to develop its own international role and the variety of interests and priorities of its member states. This third perspective was adopted in Paper II, to show the dual nature of the EU, being simultaneously a unitary entity and a conglomeration of several sovereign states.

Over time, the EU has developed into a "strange superpower" (Fraser, 2012: 1), which occupies different roles in world politics depending on the policy area. This is the result of developments which simultaneously occur internally and externally to the EU, where achievements in terms of internal integration contribute to strengthening the EU's relevance in the global arena (Bretherton and Vogler, 2006). Therefore, investigating the international nature of the EU appears to be particularly fascinating in policy areas of shared competence, where both the EU and the EU member states seek to represent their interests in international bodies (Fraser, 2012).

The level of participation of the EU in international organisations is contingent on the division of competence between the EU and the EU member states (Wessel, 2011). Usually, the EU is granted full membership in international organisations engaged in policy areas where the EU retains exclusive or extensive competence, such as trade, fisheries and some aspects of the internal market. When the EU and the EU member states share competence, the EU has varying power to develop its own international relations, albeit generally limited to a coordinating role (Fraser, 2012). In line with this argument, developing external relations remains almost exclusively a national responsibility in radio spectrum policy.

The EU may also have various rights, depending on the specific rules regarding membership of a particular international organisation (Wessel, 2011). Generally, international organisations distinguish between different member categories, which range from pure observer to full member. When it is recognised the status of observer, the EU has the right to attend meetings, but it does not have the right to participate in decision-making. Having full membership means that the EU is granted the right to take decisions. The ITU grants full memberships only to countries, while the EU is granted the status of observer. More precisely, the EU is an ITU sector member, which means that the EU can attend WRCs, but it cannot participate in decision-making. The EU member states are independent members of the ITU. In other words, they have the right to represent their own interests at WRCs and decide accordingly in the matter of radio spectrum. Notwithstanding the EU's engagement in creating a cohesive group, the EU member states take decisions at WRCs autonomously.

2.3 Business lobbying literature in Paper IV

In Paper IV, business lobbying literature was used to investigate the phenomenon of business lobbying in EU radio spectrum policy. It emerged from the review of EU integration literature conducted in Paper III that corporations and business interest groups are key actors in EU decision-making. In particular, supranational theories place major emphasis on the role of non-state actors in creating pressure for further integration (Haas, 1958, 1961; Lindberg and Scheingold, 1970; Schmitter, 2004; Pollack, 2005). As national economies within the EU become more interdependent, business interests call for centralisation of legislative power at EU level to reduce differences in national legal systems, which may hinder the establishment of cross-national business activities (Stone Sweet and Sandholtz, 1997). It became apparent that the study of the EU could not transcend the participation of corporations and business interest groups in EU public policy-making.

The phenomenon of business lobbying, or corporate lobbying (or business interest representation), can broadly be defined as the activities put in place by companies and their interest groups to influence public policy (Mahoney, 2007). Business lobbying is a phenomenon which affects all sorts of public policy-making processes in existing democratic systems (OECD, 2012). The expression business lobbying can be understood as the range of political activities put in place by business interests to influence policy and regulatory outcomes (Mahoney, 2007). The participation of business interests in public policy decision-making should not be labelled a priori as something positive or negative for the society. On the one hand, business lobbying can improve decision-making by providing decision-makers with relevant knowledge which contributes to more informed policy and regulatory outcomes (OECD, 2012; Dellis and Sondermann, 2017). On the other hand, lobbying can be detrimental to public policy-making when it is performed to persuade decision-makers to take certain decisions for the benefit of specific business interests, reducing the benefits for or even harming the public interest (Carpenter and Moss, 2013). In the EU, business interests and the EU institutions are mutually dependent. Business interests want to interact with the EU institutions to influence legislative outcomes. At the same time, the EU institutions depend upon the expertise provided by corporate stakeholders to draft EU legislation, which generally includes highly technical regulation (Greenwood, 2017).

The seminal works of Olson (1965) on the logic of collective action and Stigler (1971) on regulatory capture inspired a great number of scholars to investigate and comprehend the activities carried out by business interests to influence public policy decision-making (Carrigan and Coglianese, 2016; Laffont and Tirole, 1991). Research in economics and political sciences which investigates the capture of the regulators by the regulated industries abounds. Nevertheless, the phenomenon of business lobbying still lacks comprehensive understanding (Carpenter and Moss, 2013). Lobbying activities are often difficult to document because exercised in opaque ways. Lack of transparency and openness makes it difficult to collect robust empirical evidence (OECD; 2012; Dellis and Sondermann, 2017). One way to collect empirical evidence on lobbying activities is by means of interviews (Mahoney, 2007). In this regard, Paper II is an interview-based study which investigates the contextual factors which shape business lobbying activities in the policy field of radio spectrum in the EU.

Paper IV drew on existing studies that identified contextual factors determining the way in which the phenomenon of business interest representation occurs. These factors can be classified in three categories, each respectively covering aspects of institutions, policy issues and business interest groups. Essentially, lobbying activities would take different forms depending on the institutional context in which they take place. For instance, corporate lobbying in the EU is generally based on exchange of information between EU institutions and external stakeholders. In addition, the EU is

generally oriented towards building consensus between different stakeholders. In the United States (US), instead, business interest representatives seem to engage in more aggressive lobbying styles, as compared to the EU (Greenwood, 2017).

In addition to institutional factors, lobbying activities may take different forms depending on certain aspects of the policy issues debated. In the EU, policy issues generally generate a high degree of conflict between competing interests, which makes it difficult for one special interest to substantially influence policy outcomes (Klüver et al., 2015; Greenwood, 2017). Another important aspect is the degree of complexity of policy issues. Much of EU legislation includes highly technical regulation, for which the EU institutions possess insufficient internal resources (Greenwood, 2017). The level of complexity of EU regulation opens up opportunities for business interests to influence policy outcomes. Also, the level of public attention that a policy issue receives impacts on how business lobbying strategies are carried out. When the public is sensitive towards a specific policy issue, the opportunities for business interests to influence policy outcomes are limited as decision-makers cannot easily disregard the public opinion (Mahoney, 2007).

Characteristics of business interest groups can also affect the way business lobbying is conducted. It is common for companies to join business interest groups which represent companies' interests in a collective manner. These business interest groups may represent specific sectorial or broader interests and have more or less financial and human resources to invest in lobbying activities. Generally, larger and more resourced interest groups are expected to be more successful in influencing policy outcomes, as they have more time, money, knowledge and manpower to invest in lobbying activities (Klüver et al., 2015; Mahoney, 2007).

2.4 Radio spectrum management literature in Paper I and Paper V

In Paper I and Paper V, radio spectrum management literature was reviewed to understand the EU approach to spectrum sharing. A third element which came to light while developing Paper III was the interest of the EU in spectrum sharing. Already in 2002, the EU exhorted the EU member states to limit the assignment of individual rights of use to specific circumstances, where exclusive access to radio spectrum was unavoidable to ensure efficient spectrum use (Parliament and Council, 2009). Between 2006 and 2012 various studies, reports and opinions where published by the EU, which promoted various spectrum sharing solutions. Recently, a new spectrum sharing approach was developed by the EU, called Licensed Shared Access (LSA). This event attracted the attention of scholars to investigate the applicability of LSA to extend spectrum access for mobile technology.

Radio spectrum management literature addresses important questions such as why the radio spectrum needs to be managed and what management approaches can be implemented to deliver the highest economic and social value to society (Cave and Webb, 2015). It is possible to distinguish three approaches adopted by NRAs to manage the radio spectrum: the command-and-control or administrative approach, the market-based approach, and the technology-based approach. The administrative approach was the conventional way of managing the spectrum resource, since it started to be regulated in the 1930s (ITU and infoDev, 2007; Freyens, 2009). Under the administrative approach, NRAs issue licences to use a specific portion of the radio spectrum for a specific purpose to a limited group of users, which are selected based on pre-defined criteria. When demand for a spectrum band is limited, usage rights are given on a first-come-first-served basis. In the case of spectrum demand exceeding supply, comparative hearings or beauty contests are held in order to identify the most suitable spectrum users, among competing applicants. An additional administrative approach includes the use of lotteries, awarding licences through random selection

(Faulhaber and Farber, 2002). In the past, usage rights were given for free or against a symbolic fee (Freyens, 2009).

The administrative approach largely satisfies the need to limit the problem of interference, the NRAs having the discretion to define licence conditions to tailor the interaction between neighbouring services. At the same time, major flaws are attributed to the administrative approach, including lack of responsiveness to technological changes and dependence upon authorities' knowledge and foresight for spectrum valuation (Cave et al., 2007, Freyens, 2009). Since it is based on central planning, the administrative approach is often slow, lacking the flexibility necessary to promptly respond to and enable technological changes. In addition, it relies on the assumption that NRAs have the knowledge to select uses and users that will maximise the value of spectrum (Cave et al., 2007, Freyens, 2009).

Since the 1990s, market mechanisms took over (Cramton, 2002). The market-based approach usually entails the use of auction mechanisms to issue licences and the trading of licences on secondary markets, allowing for changes in ownership and use of radio spectrum during the duration of a licence (Cramton, 2002; Cave et al., 2007; Faulhaber and Farber, 2002; Freyens, 2009). The main benefit of employing an auction mechanism is to promote efficient spectrum use by allowing interest users to compete for obtaining spectrum usage rights (Madden et al, 2014). The price paid by auction winners for the usage rights is determined by the interaction between spectrum supply and spectrum demand, the winner presumably being the one who assigns the spectrum the highest value (Cave, 2002; Faulhaber and Farber, 2002). Relying on market-based mechanisms to assign spectrum licences has been instrumental in overcoming certain flaws of the administrative approach, although the market-based approach has also revealed its limitations. In fact, auctions have often led to unsatisfactory outcomes (GSM Association, 2014) and secondary markets have had limited success, at least in the EU.

The importance of wireless communications for a growing number of services and applications has triggered intense discussions among policy makers and regulators about adopting a more flexible management approach to radio spectrum. In particular, increasing attention has been devoted to technology development to enable coexistence of various spectrum uses and, in so doing, to accommodate emerging spectrum demands. Innovative sharing arrangements have been envisaged thanks to the development and implementation of intelligent technologies, such as cognitive radios, geo-location databases and spectrum sensing techniques.

For long time, the EU has been promoting spectrum sharing as the solution at the forefront to the problem of lack of available spectrum (Commission, 2012). In addition to the recent LSA framework, the EU promotes another spectrum sharing approach called Collective Use of Spectrum (CUS). The main difference between the two approaches regards the type of authorisation granted to service providers. When the CUS approach is implemented, service providers are granted a general authorisation, which allows them to access the spectrum on a licence-exempt basis. In licence-exempt frequency bands, various users are expected to coexist without interfering with one another (Cave et al., 2007). In certain circumstances, more or less restrictive conditions of use may be envisaged. Nevertheless, access is not restricted to a pre-defined number of users (RSPG, 2011).

Under the LSA approach, a limited number of spectrum users would be granted individual licences to access already occupied but underused spectrum bands. Traditionally, NRAs grant access to spectrum on an exclusive basis. However, granting exclusive property rights has often led to sub-optimal situations where the spectrum is assigned, but not fully used by licence holders. Although not fully used, the radio spectrum cannot be used by others because of the exclusivity licence holders benefit from, limiting the possibility to support additional spectrum uses (Boccardi et al., 2016;

Rebato et al., 2016). In this context, the LSA approach would facilitate the sharing of a portion of spectrum between existing and new users, under pre-defined sharing conditions. The LSA approach has only recently been introduced in the EU policy framework for radio spectrum and its potential implications for radio spectrum use are still being discussed by policy makers, industries and researchers.

In Paper I and V, the LSA approach was analysed in comparison with an analogue approach developed by the US Federal Communications Commission (FCC), known as Spectrum Access System (SAS) or Citizens Broadband Radio Service (CBRS). Both the EU and the US seem to recognise the important role of spectrum sharing to boost the implementation of 5G in their territories, while safeguarding incumbent users. The comparison was placed in the context of 5G, evaluating the characteristics of these two approaches to satisfy the spectrum needs of 5G.

The radio spectrum is an essential national asset which supports a wide variety of public and commercial services. Yet, researchers still pay too little attention to this unique natural resource. As a result, there is no cohesive body of research on radio spectrum. Researchers interested in radio spectrum management will have to rely on their investigative skills to identify seminal research works. Publications on radio spectrum research appear in a wide array of journals, as there is no academic journal specialised in radio spectrum. Research on technical issues may be addressed in journals published by the Institute of Electrical and Electronics Engineers (IEEE), such as the *IEEE Communications Magazine*. Research on policy and economic aspects may be published in journals such as the *Journal of Telecommunications Policy*, published by Elsevier, and the *Journal of Digital Policy, Regulation and Governance* published by Emerald. Relevant literature can also be found in books, Martin Cave, William Webb, and Thomas Hazlett being among those individuals who have contributed to the development of radio spectrum management literature.

3 Paradigm, methods and logical reasoning

This section describes the research paradigm chosen in order to conduct this research work. The research paradigm includes the philosophical underpinnings of research, concerned with ontology, epistemology and methodology. In addition, details are provided on the methods used to collect and analyse data. Finally, the logical reasoning followed to draw conclusions from data is outlined. Table 3 provides an overview of the choices made with respect to paradigm, methods and logical reasoning, which are explained further below in the rest of this section.

Paradigm	
Ontological position	Between realism and relativism
Epistemological position	Objective detachment
Methodology	Qualitative
Methods	
Method of data collection	Official documents (secondary data) Expert interviews (primary data)
Method of data analysis	Coding (thematic analysis)
Logical reasoning	
Deductive-inductive	

Table 3. Paradigm, methods and logical reasoning

3.1 Paradigm

A paradigm embraces the fundamental philosophical pillars of any research work. According to Guba and Lincoln (1994: 107), paradigms can be defined as "set of basic belief systems based on ontological, epistemological and methodological assumptions." Ontology is recognised as the starting point of any research (Guba and Lincoln, 1994; Grix, 2002). The researcher's ontological position corresponds to a set of assumptions of the nature of reality (Guba and Liconln, 1994). The basic question is whether reality exists or whether it is the product of human mind (Holden and Lynch, 2004). Once a clear worldview has been developed, the researcher can elaborate on epistemological considerations regarding the nature of the knowledge of reality that can be produced, and whether and how knowledge of reality is possible (Summer, 2011; Pernecky, 2017; Rosamond, 2015). Ontological and epistemological positions guide the researcher to the choice of the most appropriate research methodology, which essentially is concerned with the set of principles and tools the researcher can use to practically investigate a phenomenon and acquire knowledge (Guba and Lincoln, 1994; Holden and Lynch, 2004). A basic distinction is generally made between quantitative and qualitative methodologies (Bryman and Bell, 2011; Robson, 2011). Ontology, epistemology and methodology are interconnected: the researcher's ontological position defines the range of possible epistemological considerations, which, in turn, constrains the array of methodological choices (Guba and Lincoln, 1994; Grix, 2002).

3.1.1 Ontological position: between realism and relativism

The ontological assumption this research work stands on is of realist nature. According to ontological realism, there is one single independent reality "out there" for any phenomenon under investigation. Reality is regulated by objective rules and exists regardless of human observation (Gray, 2004). The researcher who adopts a realist ontological position believes that how things truly are and how things truly work can be observed (Guba and Lincoln, 1994). Realism stands in contrast to relativism,

another major mainstream school of thought in the field of ontology. Ontological relativism believes that there exist multiple constructions of reality, fabricated in the mind of the human observer (Guba and Liconln, 1994). The researcher who adopts a relativist ontological position believes that reality can be investigated and understood only relative to a specific framework of assessment. This implies that various and mutable constructions of reality can exist and that what can be known about reality is specific, local, and time- and context-dependent (Baghramian, and Carter, 2015; Guba and Lincoln, 1994).

In political science, the ontological question the researcher needs to address is whether an external political reality exists, independent of human conceptualisations of it and, if so, what basic elements constitute such political reality (Hay, 2013). Depending on the ontological assumptions of the researcher, the political reality may include individuals, collective formations, such states, supranational regimes, political parties, social movements, and so forth, or a combination of the above (Hay, 2013; Pettit, 2013). In this regard, the researcher needs to ask himself: "can collective actors realistically […] said to exist? If so, do they exhibit organic qualities, such that their character or nature is not simply reducible to the aggregation of the constituent units (generally individual actors) from which they are forged? Are such entities […] appropriate subjects of political analysis and, if so, what […] behavioural characteristics can be attributed to them? (Hay, 2013).

The ontological view adopted for this research work is ontological realism in the sense that the political reality investigated is constituted of political institutions and other entities, which are considered to be existing independently of their contextual background and of human observation. The reality observed is constituted of institutions which are "objectified, naturalized, [and] anthropomorphized" (Kauppi, 2010: 24), and have "wills of their own" (Kauppi, 2010: 25). Similarly, although the way the radio spectrum is conceptualised in this research can be said to be socially constructed, observations are limited to universally accepted regulations and management approaches. Such ontological position is a choice, which does not disregard the importance of other possible ontological approaches to research on radio spectrum management in the EU. On the contrary, combining different ontological stances may be fruitful for better understating the EU system (Christiansen et al., 1996).

Although realism and relativism are diametrically opposed in their assumptions, there exist ontological positions which can be situated somewhere in the middle of these two opposed poles. In this respect, the ontological assumptions adopted in Paper IV are slightly closer to ontological relativism, where the phenomenon of business lobbying is studied. In Paper IV, EU decision-making is understood as comprising not only objectified institutions and clearly defined laws, but also context-dependent informal rules. The nature of EU institutions is not only explained in terms of their formal roles and powers, but it is also linked to characteristics of the agents which work in the EU institutions and of the other actors which populate the EU context, such as companies and business interest groups. The political reality is understood as not being totally independent of its context and, therefore, it can be subject to different interpretations.

3.1.2 Epistemological position: towards objectivism

An epistemological position oriented towards objectivism was adopted to conduct this research work. Epistemological objectivism believes that reality must be investigated through the rigorous and evidence-based process of scientific inquiry (Thomas, 2005). By means of systematic observation and measurement, valid knowledge of the external empirical reality can be discovered (Guba and Lincoln, 1994: 113). Objectivists believe that the researcher and the phenomenon under investigation are independent and do not affect one another. Methodological choices to conduct research are made

objectively, putting aside subjective aspects, such as personal interests, previous knowledge, personal values, and skills of the researcher. Proponents of epistemological subjectivism stand at the opposite pole (Guba and Lincoln, 1994).

The researcher holding a subjectivist epistemological position argues against processes of discovery of what constitutes reality. This is because there is no single true empirical reality, but reality is constructed through the cognitive processes of the researcher. Different constructions of reality can co-exist, albeit contradictory, constructions being contextual, time- and space-dependent and varying according to the subject investigating the phenomenon (Gray, 2004; Summer, 2011). This implies that knowledge of reality cannot be discovered, but only subjectively acquired. Knowledge is understood as that set of "constructions about which there is relative consensus among those competent" (Guba and Lincoln, 1994: 113). Subjectivists believe that the researcher and the phenomenon under investigation are interdependent. Knowledge about reality reflects the researcher's background, interests, personal values, and skills (Flick, 2009; Holden and Lynch, 2004).

The epistemological position chosen to conduct this research work can be said to be objective epistemology as conceptualised by Guba and Lincoln (1994: 108). According to these authors, the posture of the researcher is "one of objective detachment or value freedom in order to discover how things really are and how things really work." At the same time, it is acknowledged that the nature of the knowledge produced in this thesis work is contingent on personal biases. Biases are tendencies to reason in a certain way due to pre-existing knowledge, skills and expectations on the process of collecting, analysing and interpreting data (Halldórsson and Aastrup, 2003). As stated by Robson (2011: 15) "you can't leave your humanity behind when doing research."

The endeavour towards objectivity is shown in the choice to conduct this research systematically, sceptically and ethically (Robson, 2011: 15). This research was conducted systematically, in the sense that an organised and well-documented research process was followed, which is illustrated in this introducing document. This research work did not have a pre-determined design. On the contrary, it developed over time. The main purpose remained unchanged over the course of the research process, while theoretical and methodological choices were made set-by-step, based on the acquired level of knowledge and expertise. This introducing document attempts to provide a detailed description of the choices made with regard to literatures and methods of data collection and analysis.

As suggested by Guba and Lincoln (1994), the sceptical attitude is to be understood as the choice to rely on well-established literatures and the views of the critical community, including editors, anonymous reviewers and professional peers which have been scrutinizing and questioning this research work. An effort was made to improve the research process and its outcome by letting independent experts review this research work at different points in time.

Conducting research ethically was understood in terms of being as comprehensive and exhaustive as possible in relation to data collection and analysis. Most of this research is based on secondary data collected from official documents, in particular documents published by the EU institutions. In order to be comprehensive in relation to collection of secondary data, an extensive number of documents was gathered, which is shown in the relatively long lists of references which accompany the five papers included in this thesis. Potential biases might be present in documents, as they are generally drafted for a specific purpose (Flick, 2009). Therefore, choosing documents from different sources can be seen as a form of triangulation to limit the risk of conducting research relying on biased information (Flick, 2009). This is why documents published by various EU institutions and other European and international entities on the same issues were used. In relation to primary data collected

by means of interviews, the ethical approach translated into safeguarding the interests and concerns of the interviewees. For the interview-based study included in Paper IV, the interviewees were approached by clearly stating the purpose of the study and the destination of use of the collected data. In addition, all the interviewees were treated anonymously. In relation to data analysis, a software for data analysis was used extensively, although not thoroughly, which ensured that a rigorous approach was followed, enhancing transparency and quality of the research investigation (Bazeley and Jackson, 2013).

3.1.3 Qualitative methodology

A qualitative approach was chosen to gain a detailed understanding of the phenomenon being investigated. Contrary to quantitative research, which generally involves statistical quantification to measure features of the reality under investigation, qualitative observations attempt to identify, define and categorise such features (Webley, 2010). Formulating concepts and organising them in a systematic fashion are two central activities in qualitative research (Webley, 2010). In addition, the reality is observed in its natural settings, rather than in an environment constructed by the researcher to test hypotheses extracted from theory (Patton, 2002; Golafshani, 2003; Webley, 2010).

This research work is mainly descriptive, providing a detailed representation of various aspects of radio spectrum management in the EU and an extensive explanation of the nature of certain problems identified. In addition, visibility is given to the complexity and the dynamic nature of the EU system, due to the tension between its supranational and intergovernmental characteristics. Yet, this thesis contains some analytical points, critically reflecting upon the relationships between the different actors involved in radio spectrum management in the EU. There is value in conducting descriptive research work as there is very limited research which describes how the radio spectrum is actually managed in the EU. By explaining how the EU institutions work and how they act, also in relation to other private and public organisations, this thesis lays the foundations for an analysis of how the radio spectrum management decision-making process in the EU actually takes place. Describing how the radio spectrum is currently managed is a first step that must occur before critiques can be formulated and potential changes proposed.

The quality of this research work can be discussed in relation to the four quality criteria shown in Table 4 (Lincoln and Guba, 1985; Bryman and Bell, 2011).

Quality in qualitative research	
Credibility	The research findings represent truthfully the reality under investigation
Transferability	A thick description of the research process is provided which enables another interested researcher to make a transferability judgement
Dependability	The research findings are consistent with the data
Confirmability	The findings represent solely the outcome of the research investigation

Table 4. Four criteria to assess quality of qualitative research
Source: based on Lincoln and Guba (1985)

Credibility is concerned with the degree to which research findings represent truthfully the reality under investigation and corresponds to the internal validity criterion used in quantitative research (Bryman and Bell, 2011; Lincoln and Guba, 1985). According to Lincoln and Guba (1985), three activities can be carried out to ensure credibility. These activities are: prolonged engagement, persistent observation, and triangulation. Prolonged engagement refers to the investment of time and resources in understanding the context in which the phenomenon under investigation is embedded. Persistent observation concerns the identification of salient issues or problems to be addressed.

Finally, triangulation refers to the use of multiple sources, theories, methods, and investigators, as also suggested by Denzin (1978). Effort were put into carrying out these activities in order to produce credible findings.

In relation to prolonged engagement, this research work was presented in various international academic events. Some of them were specialised in Information and Communication Technology (ICT) topics, such as the Telecommunications Policy Research Conference (TPRC), the annual scientific seminar of the Florence School of Regulation (FSR) Communication and Media and several PTC and ITS conferences. Some other events were centred on EU policy and legal issues, such as the annual conference of the Swedish Network for European Studies in Political Science (SNES) and the annual workshop of the Swedish Network for European Legal Studies (SNELS). Participating in these events provided the opportunity to receive observations and comments from experts in both telecommunications policy and EU research, not involved in this research project. The academic conferences where various parts of this work were presented are listed in Table 5.

Time	Place	Event	Organiser
June 2014	Brussels	Annual regional conference	ITS
Sept. 2014	Arlington	Annual conference	TPRC
March 2015	Florence	Annual scientific seminar	FSR
June 2015	San Lorenzo de El Escorial	Annual regional conference	ITS
Nov. 2015	Rio de Janeiro	Biennial conference	ITS
Oct. 2015	Los Angeles	Annual regional conference	ITS
June 2016	Taipei	Biennial conference	ITS
Jan. 2018	Honolulu	Annual conference	PTC
April 2018	Gothenburg	Annual conference	SNES
June 2018	Seoul	Biennial conference	ITS
Aug. 2018	Trento	Annual regional conference	ITS
Aug. 2018	Stockholm	Annual workshop	SNELS
Jan. 2019	Honolulu	Annual conference	PTC

Table 5. List of academic conferences

In addition, various workshops, conferences and seminars organised by policy-makers, regulators, and corporate stakeholders interested in radio spectrum policy and regulation in the EU were attended. Examples of events which were attended as part of this research work include the annual European spectrum management conference, the leading platform for spectrum management discussions in the EU; the annual telecom summit organised by LS Telcom, LS Telcom being a multinational company specialised in radio spectrum technology; the annual workshop on radio spectrum organised by the Independent Regulators Group (IRG), IRG being a group of NRAs from thirty-seven European countries; a stakeholder workshop organised by the Radio Spectrum Policy Group (RSPG) of the EU and other events organised by the Swedish Post and Telecom Authority (PTS), the Swedish NRA, and the Italian Communications Regulatory Authority (AGCOM), the Italian NRA. Table 6 shows the stakeholder workshops, conferences and seminars which were attended.

Time	Place	Title	Organisers
June 2015	Brussels	Annual European spectrum management conference	Forum Europe
June 2015	Lichtenau	Annual telecom summit	LS Telcom
Oct. 2015	Brussels	Workshop on “Pascal Lamy talks spectrum policy, creative sector, jobs and diversity”	Wider Spectrum Group

Time	Place	Title	Organisers
Aug. 2015	Brussels	Capacity-building workshop on spectrum	IRG
June 2016	Brussels	Annual European spectrum management conference	Forum Europe
Nov. 2016	Stockholm	Seminar on current research topics	PTS
March 2017	Brussels	Workshop on spectrum assignment in the EU	LS telcom, PolicyTracker, and Valdani Vicari & Associati
March 2017	Rome	Workshop on 5G	AGCOM
Sept. 2018	Dublin	Stakeholder workshop	RSPG
Nov. 2018	Stockholm	Seminar	PTS

Table 6. List of stakeholder conferences, workshops and seminars

Engagement in a number of research projects on various radio spectrum policy issues also contributed to understanding the reality under investigation in this research project. An example is the research project titled "Regulation in the age of convergence: best practices in spectrum allocation methods," carried out in 2016 for the National Broadcasting and Telecommunications Commission of Thailand. For the scope of this project, interviews were conducted with representatives of PTS, AGCOM, and the Office of Communications (Ofcom), the NRA in the UK. Furthermore, two internships were undertaken in 2017, at the National Media and Infocommunications Authority, the Hungarian NRA, and at Deutsche Telekom in Germany. Interacting with and observing individuals who take part in decisions involving spectrum management was fundamental to gain the tools to critically interrogate and understand the issues discussed in this thesis.

Persistent observation consisted in activities to stay up to date with ongoing discussions on policy and regulatory issues related to radio spectrum use. Following policy debates and legislative interventions at EU level was key to identify the most salient issues, at the EU level, related to radio spectrum management. In addition, reading radio spectrum related news was instrumental in capturing the views of relevant stakeholders, including companies and business interest groups. In particular, news published by PolicyTracker, the online newsletter exclusively dedicated to radio spectrum policy and management, and corrierecomunicazioni.it, were followed.

Triangulation is a common technique employed to strengthen the credibility of qualitative research findings (Denzin, 1978; Patton, 2002; Bryman and Bell, 2011). In this research work, triangulation of sources was employed by gathering the same information from different sources, in particular from official documents, published by different EU and international entities, news articles, and reports from various stakeholders. Triangulation of methods was used to a limited extent, in particular with respect to methods of data collection. Data was mainly gathered through documents and, to a limited extent, from expert interviews. In addition, information provided by the interviewees, for instance in relation to particular events, was checked against documents. Triangulation of theories was also performed, adopting various widely accepted theoretical concepts to organise and interpret the collected data. The use of multiple investigators was implemented in Paper V, involving another researcher in defining the purpose, collecting and analysing data, and drawing conclusions.

Transferability concerns the responsibility of the researcher to provide a thick description of the research context and process, which is detailed enough to allow other interested individuals to make a transferability judgement. Essentially, a transferability judgement is an assessment of whether the findings of a study can be transferred to other contexts. To satisfy the transferability criteria in this research project, a rich account of information was included in each appended research paper

describing the contextual background of the specific issues addressed and a detailed explanation of the choices made, related to theoretical framework, collection and analysis of data, formulating also suggestions for future research.

A widely used technique to assess both dependability and confirmability is to undergo a so-called external audit (Guba, 1981). Dependability requires that the research findings are consistent with the data. Dependability corresponds to the concept of reliability used in quantitative research, according to which an experiment is reliable when it leads to the same results, if conducted by other researchers. Confirmability is concerned with ensuring that the findings represent the outcome of the research investigation, rather than the point of view, motivation or interest of the researcher. During an external audit, the processes of data collection, data analysis, and the resulting interpretations, findings and recommendations are examined by a third party (Guba and Lincoln, 1985).

The approach adopted to guarantee dependability and confirmability of this research work consisted in three main activities. First, this work was assessed by researchers external to this research project at three events over the course of five years, before the final doctoral thesis was defended in December 2019, as required by the graduate school of the Department of Technology Management and Economics at Chalmers University, where this research was conducted. These three events, which are a research proposal seminar, a licentiate level seminar and a final seminar, can be seen as three different phases of an audit process. On 8th May 2015, the research proposal seminar was convened. During the seminar, a research proposal was presented to two external auditors. Prior to the seminar, both auditors had been provided with a ten-page description of the research proposal, which was then discussed in detail during the seminar. In particular, the fit between methodological choices related to purpose, theoretical framework, method of data collection and analysis was examined. On 9th February 2017, a mid-term thesis was presented at the licentiate seminar to an external auditor, which was provided with the manuscript beforehand. In the occasion of the licentiate seminar, the external auditor not only examined the research work, but also provided suggestions as for how to move forward in developing the research investigation. On 30th April 2019, this work was scrutinised once again by an external auditor, which provided an assessment of this thesis and a recommendation as to how to make some minor adjustments to this thesis before the public defence.

Second, this research was scrutinised by academics from various research environments at the PhD workshops and academic conferences listed in Table 5. Third, this work was periodically audited by Professor Erik Bohlin and Associate Professor Violeta Roso, as part of their supervisory role. Comments received at these auditing instances were used to improve the research work, either by implementing changes or by explaining more carefully the choices made.

3.2 Methods of data collection and analysis

Methods can be defined as the procedures carried out by the researcher to collect and analyse data (Blaikie, 2000). Methods are seen as independent of the researcher's paradigm. This means that the same method can be used under different ontological, epistemological and methodological assumptions (Saldaña, 2016). The choice of methods of data collection and analysis should be generally guided by the research questions the researcher wants to answer (Grix, 2002).

To answer my two research questions concerning respectively the entities which manage the radio spectrum in the EU and the mechanisms such institutions take part in, secondary data was mainly collected from official documents, for three main reasons. First, as stated by Gupta (2011:192), most public policy research involves the use of secondary data. For this research work, information on EU

policies and laws needed to be collected in order to fully understand how the EU works. The official documents used for gathering secondary data contain plenty of information regarding decision-making for radio spectrum management in the EU. In addition, they also provide a great deal of background information to better understand why certain decisions are taken (Shanton, 2004; Bowen, 2009).

Second, the official documents used are widely and freely available online. A great advantage of gathering data from documents is, in fact, related to their availability (Bowen, 2009). The EU institutions, agencies and bodies publish a wide variety of documents, including legislative and non-legislative acts, as well as reports and other types of documents (EU, 2019). Similarly, documents produced by other bodies involved in radio spectrum management, such as the ITU, the CEPT, the European Telecommunications Standards Institute (ETSI), are also publicly accessible.

Third, the content of these official documents is generally determined by a negotiated compromise between a diverse group of stakeholders (Commission, 2017b). Although documents must be examined critically, as they may reflect interests and perspectives of their authors (Saldaña, 2016), their content may be less biased if they are the result of a collective preparation process which involves stakeholders with different interests. In addition, knowing how the EU institutions and other EU entities work, what roles they play in the decision-making process and what interests they represent, may help in the critical analysis of their official documents.

Expert interviews as method of data collection was adopted for the study in Paper IV on EU business lobbying. Expert interviews are a specific form of semi-structured interviews, where the relevance of interviewing certain individuals is due to their specific professional sphere of activity (Robson, 2011). Interviewing individuals who are directly or indirectly involved in EU lobbying activities was necessary to draw information on how business lobbying is carried out in the policy field of radio spectrum for two main reasons. First, information on business lobbying is generally not included in official documents. Second, although newspaper articles and reports were published on the topic of lobbying, none of these documents dealt with radio spectrum policy.

Coding was the method employed to analyse qualitative data. Coding qualitative data consists of assigning a key word or phrase to a portion of text or audio-visual data, which captures a salient feature of the reality being studied (Saldaña, 2016). For this research work, textual data was coded, which consisted of official documents and interview transcripts. In addition, coding took place in a cyclical way. It is quite common that qualitative data is subject to several cycles of coding, which are necessary to identify salient features (Saldaña, 2016). Once the coding was completed, the codes were organised into overarching themes. Themes capture fundamental ideas, discussed in various ways in the coded text, which help answer the research questions (Attride-Stirling, 2001; Braun and Clarke, 2006). While codes were inductively derived from data, the reduction of codes into themes was deductively performed by applying pre-existing themes. Such themes corresponded to consolidated theoretical concepts in the literatures this research work drew upon.

3.2.1 Collecting data from official documents

Secondary data was collected from official documents published by NRAs, EU institutions and bodies, and European and international entities. All these organisations make their documents available on their websites. Table 7 provides an overview of the main official documents used for this research work.

Context	Document Type	Organisation	Purpose of the document
National	Deliberation	AGCOM	Communication of a decision. Its content can be quite varied. Examples are: a decision to hold a public consultation and a decision regarding the rules of an assignment procedure
	Notice of Inquiry; Notice of Proposed Rulemaking; Report and Order	FCC	Published during the decision-making process. First, a Notice of Inquiry is published to collect information from stakeholders on a specific topic. Then, a Notice of Proposed Rulemaking is issued to describe potential changes to existing rules. Stakeholders are invited to provide comments. Finally, a Report and Order is issued containing the changes which will be implemented
	Consultation	Ofcom	Published during the decision-making process. First, a Consultation is published to collect information from stakeholders on a specific topic. After a consultation period, a decision is taken and published in a Statement. Its content can be quite varied, including, for instance, the rules of an assignment procedure or Ofcom's annual working plan
	Statement		
	Report		Provision of information about e.g. the performance of a specific sector or service
	Strategy	PTS	Published to outline vision and long-term objectives with respect to spectrum use
EU	Opinion	BEREC	Expression of viewpoint on a specific issue
	Communication	Commission	Published with various purposes, e.g. expression of viewpoint or recommendations. Legislative proposals are also published in the form of Communications
	Implementing acts		Legally binding conditions for the uniform implementation of EU law across the EU
	Green paper		Consultation documents on a specific topic to stimulate discussions among interested stakeholders at EU level. Green papers may lead to legislative proposals
	Action plan		Laying out actions to reach a certain result. Actions plans are not legally binding for the EU member states and/or citizens
	Resolution	Council, Parliament	Recommendation to act in a given policy area. Resolutions are not legal binding for the EU member states and/or citizens
	First reading position		Adopted in the context of the OLP. The OLP starts with the simultaneous submission of a legislative proposal to the Parliament and the Council. The Parliament, at first reading, can decide to adopt the proposal as it is or formulate amendments. The Parliament's first reading position is sent to the Council. The Council adopts its first reading position. The Council can decide to agree with the Parliament's position or to propose amendments

Context	Document Type	Organisation	Purpose of the document
EU	Conclusions	Council	Political position on a specific topic, generally adopted after a debate during a Council meeting. They do not have legal effects
	Regulation	Council and Parliament	EU legal instrument aimed at harmonising national legal systems. Regulations do not need to be transposed into national legislation
	Decision		EU legal instrument aimed at removing national differences addressing one, a group or all EU member states depending on the circumstances. A decision can also be addressed to individuals and organisations. They do not need to be transposed into national legislation
	Directive		EU legal instrument which specifies objectives to be achieved by the EU member states. Directives can be addressed to a single, a group or all EU member states. Contrary to regulations and decisions, directives are not directly applicable. They have to be transposed into national legislation. It is up to each EU member state to decide what type of domestic legal instrument to adopt in order to reach the objectives specified in the directives
	Treaties	European Council[1]	Laying down the objectives of the EU and regulating the relationship between the EU and the EU member states. The EU treaties have from time to time been amended to reform the EU institutions and to give it new areas of responsibility. They have also been amended to allow new EU countries to join the EU. The treaties are negotiated and agreed by the EU countries and then ratified by their parliaments, sometimes following a referendum
	Opinion	RSPG	Expression of viewpoint on a specific issue. Opinions are generally adopted to advise the Commission
	Report		Published on a wide variety of issues. The purpose of a report can be to explain concepts and share best practices, to analyse current issues, or to provide information on the RSPG's performance
European	Report	CEPT	Dissemination of results of studies conducted by the Electronic Communications Committee (ECC) of the CEPT. Report are published in support of ECC Decisions, ECC Recommendations or ECPs
	Decision		Measures to harmonise the use of radio spectrum across the CEPT countries. Drafted by consensus, ECC Decisions are widely supported and adopted by individual countries, even though they are non-binding
	Recommendation		Measures that NRAs are encouraged to apply. They are principally intended as harmonisation measures for those matters where ECC Decisions are not yet relevant, or as guidance to NRAs
International	Report	ITU-R	Technical, operational or procedural statement, prepared by a Study Group on a given subject

[1] The European Council is the summit conference of heads of state or government of the EU Member States (EU, 2012).

Context	Document Type	Organisation	Purpose of the document
International	Recommendation	ITU-R	International technical standards. They are the result of studies undertaken by Study Groups. Their implementation is not mandatory. However, they enjoy a high reputation and are implemented worldwide as they are developed by experts from national administrations, the industry and other organizations dealing with radiocommunication matters from all over the world
	Resolution		Instructions on the organization, methods or programmes of Radiocommunication Assembly or Study Group work
	Final acts		Record of the decisions taken at a WRC, comprising both new and revised provisions of the RR, including all Appendices, and the new and revised Resolutions and Recommendations approved at WRC

Table 7. Overview of main official documents used to gather secondary data

A snowball sampling procedure was used to gather official documents relevant for this research work. This procedure is widely used in qualitative studies where data is gathered by means of interviews (Biernacki and Waldorf, 1981). In order to implement a snowball sampling procedure, an initial random sample of interviewees is identified. Then, each interviewee in the initial sample is asked to name other potential interviewees to enlarge the sample (Goodman, 1961). In this research work, a similar procedure was applied to documents. The initial sample of documents included documents outlining international and EU radio spectrum rules currently in force. These documents included references to documents published in previous years, which were gathered to enlarge the initial document sample. Over time, additional documents were added to the document sample as soon as they were published. Moreover, specific searches were conducted to gather documents containing information on specific issues, browsing certain websites, such as the ITU's website; EUR-lex, the official portal to access EU law;[2] the EU radio spectrum policy document archive;[3] and the websites of the RSPG and various NRAs.

The quality of the secondary sources used can be discussed in relation to the four evaluating criteria proposed by Scott (1990). These criteria are indicated in Table 8 and further explained below.

Quality criteria	
Authenticity	The document is of clear authorship and its content is integral
Credibility	The document represents truthfully the reality under investigation
Representativeness	The document is essential for conducting the research project
Meaning	The document is clear and understandable

Table 8. Criteria for evaluating secondary sources of data
Source: Scott (1990)

Authenticity considers whether secondary sources are of unquestionable origin and whether their content has not been altered. In this regard, it can be argued that the documents used for this research work are of clear authorship. The Transparency Regulation (Parliament and Council, 2001) and the case law of the Court of Justice of the EU (CJEU) require that complete access to EU official documents is granted to the public, especially when it comes to legislative documents. Generally, the EU strives to guarantee transparency of its decision-making processes and availability of information on how decisions are taken to the public, although whether the EU can be considered accountable is often questioned (Gustafsson et al., 2009).

Credibility refers to whether the content of secondary sources represents truthfully the reality under investigation. As previously mentioned, credibility of the documents used would stem from the fact that they are generally the outcome of long debates among stakeholders with different interests. This may, to some extent, even out the presence of biases.

Representativeness ascertains whether the secondary sources considered by the researcher are representative of the totality of the relevant secondary sources. In other words, none of the essential sources are left out. In relation to representativeness, the strategy adopted in this research work was to stop gathering additional documents when no new information was emerging. Although it cannot be claimed with certainty that all relevant documents were considered, an extensive number of documents was scrutinised during this research process. It can also be mentioned that radio spectrum

[2] EUR-lex, https://eur-lex.europa.eu/homepage.html
[3] EU archive, https://ec.europa.eu/digital-single-market/en/radio-spectrum-policy-document-archive

regulation in the EU is a rather circumscribed area, which also entails the collection of a relatively limited number of documents.

Finally, meaning aims to assess whether secondary sources are comprehensible and clear. Generally, the degree of comprehension and clarity of documents depends on the expertise of the reader. In this regard, efforts were put in developing a suitable level of knowledge with regard to both radio spectrum management and EU public policy-making. For instance, a course on radio spectrum management was taken in April 2015, organised by PolicyTracker and LS Telcom. A post-graduate certificate in EU policy making offered by the Institute for European Studies of Vrije Universiteit Brussel was acquired in 2016 to develop a thorough understanding of the EU system and its main features. Moreover, the annual training on "Business models, innovations, and regulation of the digital world" organised by FSR Communication and Media, was completed between 2016 and 2017, to understand the regulatory challenges brought about by the phenomenon of digitalisation.

3.2.2 Collecting data by means of expert interviews

Paper IV is based on primary data collected by means of expert interviews. In particular, ten experts were interviewed to collect information on EU business lobbying in the policy field of radio spectrum. The interviews were conducted over Skype, with the exception of one interview which was conducted over the phone. Table 9 provides basic information about the interviewees. As the interviewees are treated anonymously, their names and affiliations are not disclosed. Interviewees were divided into broad categories, corresponding to entities directly or indirectly involved in EU business lobbying in radio spectrum policy.

Category	Number of interviewees	Source of knowledge about EU business lobbying in radio spectrum policy
EU institutions	1	Direct experience as subject being lobbied by business interest groups for radio spectrum policy matters
Business interest groups	1	Direct experience as subject lobbying EU institutions for radio spectrum policy matters
Small-size companies	1	Direct experience as subject lobbying EU institutions for radio spectrum policy matters, both individually as well as part of business interest groups
Multi-national companies	2	Direct experience as subjects lobbying EU institutions for radio spectrum policy matters, both individually as well as part of business interest groups
Consulting companies	2	Direct experience as subjects lobbying EU institutions for radio spectrum policy matters, in representation of specific business interests
Non-governmental organisations	1	Indirect experience gained by collecting data and publishing research studies and news articles on EU business lobbying in the EU in various sectors, including the telecommunications sector
Media	2	Indirect experience gained by collecting data and publishing news articles on EU radio spectrum policy and by regularly interacting with subjects lobbying EU institutions as well as with the EU institutions lobbied for radio spectrum policy matters

Table 9. Information about interviewees
Source: Paper IV

A snowball sampling procedure was used to build the sample of interviewees. An initial sample of interviewees was identified among experts met in conferences, workshops and other events. Then, these experts were asked to name other potential interviewees to be included in the sample. All interviewees were contacted via e-mail or via LinkedIn. Some persons which were contacted did not respond. Only one person clearly refused to participate in the study. It must be said that collecting

information by means of interviews in a sensitive policy area such as radio spectrum policy was challenging. Individuals who work in the field are generally reluctant to share information which may be associated to the public or private organisations where they are employed.

All potential interviewees were informed that interviews would be recorded and treated anonymously. The participants were also provided with an interview guide. The interview guide contained eight open-ended questions which were asked during the interview. Interviews were recorded and transcribed. Although transcribing is a time-consuming procedure, it was important to record and transcribe interviews, for three main reasons. First, efforts were put in following the conversation with the interviewees, rather than on taking notes during the interviews. Second, the content of the interviews was available at any time after the interviews were conducted. Third, the interview transcripts needed to be coded for the analysis.

3.2.3 Thematic analysis

Thematic analysis is the type of coding which was performed to analyse the data (Braun and Clarke, 2006). It is generally described as a technique of pattern recognition across a data set (Braun and Clarke, 2006; Fereday and Muir-Cochrane, 2016). The researcher plays an active role in identifying patterns, also called themes, selecting the most interesting ones, and reporting them to the reader (Taylor and Ussher, 2001). In particular, a theoretical thematic analysis was conducted, whereby the data was coded on the basis of a theoretical frame of reference previously defined by borrowing from existing literatures (Braun and Clarke, 2006).

The theoretical thematic analysis was conducted in two steps. First, the texts, i.e. official documents and interview transcripts, were coded. Second, codes were clustered into overarching themes. These themes corresponded to the theoretical concepts to be explained. The purpose of conducting a theoretical thematic analysis is to focus on specific aspects of the data set, which are relevant for the research questions, instead of providing a rich description of the overall data set (Braun and Clarke, 2006). Table 10 here below provides an overview of the themes, i.e. the main theoretical concepts used in this thesis.

Paper	Themes	Description
II	Agenda-setting Coalition building	Concepts borrowed from international relations literature because identified as key determinants of outcomes of international negotiations. Used in Paper II to discuss the capability of the EU to reach its objectives at WRCs
III	Supranationalism Intergovernmentalism	Basic views of supranational and intergovernmental theories of EU integration used in Paper III to show the tension between the aim of the EU to harmonise radio spectrum across the EU and the opposition of the EU member states to restrictions to their national sovereignty
IV	Institutions Policy issues Business interest groups	Contextual factors which shape business interest representation, according to existing research on business lobbying. Used in Paper IV to understand business lobbying in EU radio spectrum policy
I & V	Exclusive/shared use Licensed/unlicensed use Coordinated/uncoordinated use	Characteristics which help discern different types of spectrum sharing approaches. Used in Paper I and V to compare LSA with other sharing approaches, such as CUS and CBRS

Table 10. Overview of the themes used to conduct thematic analysis

Thematic analysis was conducted with the support of the software Nvivo in Paper II, IV, V. It was not used for paper I and III because these two papers where already at a relatively mature stage of development when Nvivo started to be used. Nvivo was used to satisfy three major needs: the identification of themes, the coding of texts and the overall organisation of the material used for this thesis. First, Nvivo was used to identify the theoretical constructs used as analytical tools. Nvivo

simplified the review of the relevant literatures, offering a platform where research articles and book chapters could be uploaded and main ideas identified and organised, at the same time maintaining ready access to the articles and book chapters where those ideas were discussed. Second, Nvivo was a useful tool to perform coding. An overview of all codes produced could be easily visualised, grouping together similar codes, without losing track of data sources. It was quite easy to re-code the texts and eventually to group similar codes under overarching themes. Third, Nvivo provided an easy way to keep a well-structured storage of the material used for this research work. This included not only official documents and interview transcripts but also published research and other documents used to develop various aspects of the papers appended to this introducing document.

3.3 Iterative inductive-deductive logical reasoning

This research work was based on an iterative inductive-deductive relation between theoretical and empirical worlds (Box, 1976; Rossiter, 2011). As illustrated in Figure 5, the process of learning and understanding the phenomenon under investigation was the result of moving back and forth between deductions from theory and inductions from empirical data (Box, 1976; Rossiter, 2011).

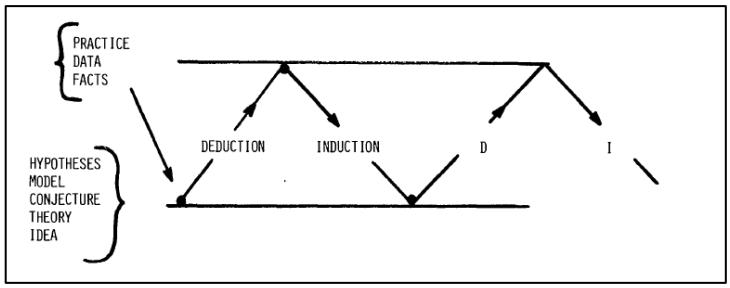

Figure 5. Iterative inductive-deductive logical reasoning
Source: Box (1976)

Adopting such logical reasoning was not a choice taken a priori. The need to adopt a multi-perspective approach, relying on different literatures, arose during the research process to analyse the complex nature of radio spectrum management. Thanks to this iterative inductive-deductive logical reasoning, research questions, literatures and data were matched. It is quite common for qualitative researchers to adopt a flexible research design which can be adjusted in correspondence to the knowledge accumulated during the research process (Maxwell, 2013).

4 Summary of appended research papers

This section provides short summaries of the five appended research papers. Each summary briefly presents aim, theoretical considerations, methodological aspects, results, contributions and main limitations of each paper.

4.1 Paper I

Massaro, M. (2017) Next generation of radio spectrum management: Licensed shared access for 5G, *Telecommunications Policy,* 41(5-6): 422–433. DOI: https://doi.org/10.1016/j.telpol.2017.04.003.

In Paper I, radio spectrum management approaches which allow radio spectrum to be shared were examined. Radio spectrum is shared when different groups of users coexist in the same spectrum band. This study was motivated by the engagement of the EU in acknowledging and disseminating the concept of spectrum sharing across the EU. Spectrum sharing is a concept which has been part of the EU policy and legislative framework for long time. Recently, the EU designed a new spectrum sharing approach, called LSA, to accommodate the need to find additional radio spectrum for mobile internet services. In this respect, the aim of Paper I was two-fold: first, to assess the degree of novelty of LSA with respect to the existing CUS, which include licence-exempt and light-licensing sharing approaches; second, to identify main differences between LSA and a similar approach recently developed in the US, known as SAS or CBRS. Information on these radio spectrum management approaches was gathered from various types of documents, including policy documents, academic papers, position papers and analysis reports. Paper I is essentially a survey article, which provides a review of recent policy developments in radio spectrum sharing.

With regard to the first aim, Paper I showed that LSA enables a way of sharing radio spectrum, which is not satisfied by licence-exempt and light-licensing. The novelty stands on the possibility for a limited number of new spectrum users to share radio spectrum with incumbent users on a licensed basis. All spectrum users would have the right to protection from harmful interference and the obligation to comply with sharing conditions included in their licences. With regard to the second purpose, the comparison between LSA and SAS indicated that LSA is characterised by a lower degree of technical complexity. This is due to the fact that LSA would allow two groups of users to share a certain portion of the radio spectrum, while SAS foresees the creation of three layers of users with different rights and obligations which would share spectrum in a dynamic manner.

Paper I contributes to spectrum management literature which focuses on spectrum sharing, by discussing how spectrum sharing is conceptualised and promoted by the EU. In addition, Paper I attempts to highlight the importance of the role of the EU in radio spectrum management by using the US as benchmark for the EU. If one should only look at the distribution of regulatory responsibilities for the radio spectrum, the EU and the US would be hardly comparable. In the US, the responsibility to manage the radio spectrum is carried out by two entities, the FCC and the National Telecommunications and Information Administration (NTIA). The FCC is an independent regulatory agency which is responsible for the non-federal use of the radio spectrum, including commercial use. The NTIA is a unit of the Department of Commerce, which administers the radio spectrum dedicated to federal uses, for instance for defence services. Although the EU may have some resemblances to a traditional federal polity, its regulatory responsibilities in radio spectrum management are quite different as compared to the US. In particular, the EU does not have the power to oblige the EU member states to implement sharing approaches. Notwithstanding that, this paper showed that the EU and the US sometimes carry out comparable activities, both entities dedicated to

the promotion of radio spectrum sharing in their territories. From a practical point of view, Paper I contributes to the ongoing discussion between policy-makers, industry practitioners and researchers on how to find additional radio spectrum for mobile internet services. At the time of writing of Paper I, LSA and SAS were at an early stage of development.

As stated earlier, Paper I is a survey article where spectrum management approaches are explained and compared in their theoretical conceptualisation, without an analysis of practical applications. This may be considered the main limitation of this paper. For instance, gathering information on the actual implementation of sharing approaches in the EU member states would contribute to a deeper assessment of the novelty of LSA and its relevance to meet the increasing demand of radio spectrum for mobile internet services.

4.2 Paper II

Massaro, M. (2018) Radio spectrum regulation as a matter of international affairs: discussing the effectiveness of the European Union at World Radiocommunication Conferences, *Digital Policy, Regulation and Governance,* 20(5): 373–398. DOI: https://doi.org/10.1108/DPRG-09-2017-0049.

Paper II aimed to discuss EU effectiveness in international negotiations on radio spectrum regulation, where effectiveness was intended as the capability of the EU to reach its objectives in specific multilateral settings. To this aim, a comparison was made between the objectives of the EU prior to and the outcomes of three WRCs, respectively held in 2007, 2012 and 2015. The degree of match between EU's objectives and WRCs' outcomes was taken as illustrative of EU effectiveness. Despite its involvement in policy and regulatory discussions on radio spectrum use at international level, very little is known about the external representation of the EU in ITU-R. Paper II showed the complex functioning of the EU system, both the EU and the EU member states representing their interests at WRCs.

The concepts of agenda-setting and coalition-building were borrowed to discuss EU effectiveness. Agenda setting and coalition building are two key features of public policy-making (Birkland, 2015). Agenda setting can be described as the collection of actions undertaken by interested stakeholders to earn their issues a place on the agenda and to keep others' issues off the agenda. The agenda contains all issues which are going to be discussed and potentially acted upon by decision-makers. Competition arises among interested stakeholders because decision-makers have limited resources. Therefore, only a finite number of issues can be placed on the agenda and an even smaller number of issues can be acted upon (Birkland, 2007, 2015). Finding a place on the agenda is crucial, not only because of the limited scope of the agenda, but also because the stakeholders who succeed in influencing the agenda will also dominate the policy debate and potentially influence public policy outcomes (Schattschneider, 1975; Birkland, 2007, 2015). The ability of stakeholders to influence the agenda generally increases when actors form coalitions. This is because issues that find support from a large number of actors usually gain more visibility in policy discussions and, therefore, they are more likely to be placed on the agenda (Birkland, 2007; Baumgartner, 2010).

Secondary data was gathered from official documents to identify the objectives of the EU and the outcomes of WRCs. The objectives of the EU were identified taking into considerations the proposals respectively of the Commission, the EU member states, and the CEPT, as they all contribute to represent the interests of the EU at WRCs. Secondary data was coded in Nvivo, using the concepts of agenda-setting and coalition-building as overarching themes to discuss the degree of conflict between the positions adopted by the Commission, the EU member states, and the CEPT with respect

to the agendas of the three WRCs studied, as well as the formation of coalitions between the CEPT and other regional organisations.

The analysis in Paper II showed that it is difficult to ascertain whether the EU was effective in achieving its objectives during the three WRCs considered, mainly because of the different priorities of the Commission, the EU member states, and the CEPT. Nevertheless, the analysis provided interesting insights on the external representation of the EU. In particular, the EU resorts to legal actions to bind the EU member states to act as a cohesive group at WRCs. In addition, the Commission formally cooperates internally with the RSPG, a high-level advisory group which offers assistance to the Commission in the development of radio spectrum policy, and externally with the CEPT to create consensus among the EU member states. This is because the degree of cohesiveness between the EU member states affects the capability of the EU to pursue its objectives in international organisations where the EU is not recognised full membership. In international organisations where only countries are recognised the right to take decisions, the extent to which the EU member states can promote the interests of the EU depends on the level of coordination within the EU.

On the theoretical side, Paper II contributes to existing literature on the international role of the EU. In particular, Paper II attempted to expand existing, albeit limited, research which investigates the participation of the EU in the ITU. In addition, Paper II provides a contribution to spectrum management literature. As commented by an anonymous reviewer: "[w]hile some authors have examined spectrum management issues occurring at international level, relatively few articles address how one international organisation influences another. As such, the submission addresses a clear gap in the academic literature." On the practical side, Paper II offers a first insight of how the EU takes part in WRCs and what legal and strategic instruments it uses to represent its interests, in particular in relation to the EU member states and the CEPT.

The use of "just secondary sources" represents the main limitation of this study. As explained by an anonymous reviewer: "[d]ocuments from official meetings often fail to convey the tensions […] that occur to reach a deal between stakeholders - such deals should be of interest to the author(s) as they are how the EU achieves its goals." In this regard, a follow up study based on primary data collected by means of expert interviews may provide novel information relevant for the study of EU effectiveness at WRCs. At the same time, finding individuals willing to take part in such study represents a major challenge.

4.3 Paper III

Massaro, M. (2019) Between integration and protection of national sovereignty in the European Union's radio spectrum policy: uncovering potential research avenues, *Journal of Information Policy,* 9: 158–197. DOI: https://doi.org/10.5325/jinfopoli.9.2019.0158.

Paper III is a chronological narrative of how radio spectrum policy developed in the EU. The main EU legislative interventions relevant for EU radio spectrum policy, since its inception in the 1980s to present date, were mapped. The aim was to show variation over time in competence distribution between the EU and the EU member states. The narrative was organised in four stages, each stage comprising major changes to EU legislation. Legislative revisions took place every ten years, in correspondence to the emergence of new generations of mobile technology.

Qualitative data was gathered from 60 EU official documents, including directives, decisions, regulations, communications, green papers, action plans and resolutions. Each document was summarised, and summaries were used to build the narrative. Documents were organised following

the OLP. The OLP is launched when the Commission submits a legislative proposal to the Parliament and the Council, and it concludes with either the adoption or the dismissal of the legislative proposal.

The narrative showed a constant tension between the ambition of the EU to enlarge its competence in radio spectrum policy and the opposition of the EU member states to restrictions to their national sovereignty. On the one hand, it was observed a gradual centralisation of power at the EU level, as shown by the expansion of topics covered by EU laws and the types of legal instruments adopted. Initially, the body of EU law mainly included directives. Directives are the least intrusive of all EU legal acts, as they are not directly applicable. The EU member states decide how to transpose the content of directives into national legal systems, taking into account domestic circumstances. Subsequent EU legislative reviews resulted into adoption of decisions, which contrary to directives, are directly applicable. As new EU laws affecting radio spectrum use in the EU were adopted, the executive power of the Commission acquired more weight, the Commission being generally delegated the power to adopt legally binding executive acts to promote EU-coordinated use of radio spectrum across the EU.

On the other hand, it was observed a strong opposition from the EU member states to EU interventions which would have resulted in substantial limitations to national sovereignty. This was shown by the refusal of the Council to adopt regulations to introduce major changes to existing EU legislation on radio spectrum, regulations having the most centralising effect of all EU legal instruments. Moreover, the EU member states rejected the proposal to create an EU regulatory authority responsible for radio spectrum, because it would have substantially limited the EU member states' discretion to decide on radio spectrum use in their respective territories.

From a theoretical perspective, Paper III followed the literature tradition which addresses the issue of competence distribution between the EU and the EU member states. EU policy areas are generally quite different from one another, in terms of degree of involvement of the EU and objectives pursued (Buonanno and Nugent, 2013). Therefore, studies on competence distribution have often taken a case study format, focusing on a specific policy area. The radio spectrum has become increasingly important for the EU, in particular for its contribution to the creation of the so-called digital single market. For this reason, it appeared relevant to investigate the exercise of EU legislative power in the policy area of radio spectrum, which has so far received limited attention from scholars. In addition, Paper III contributes to spectrum management literature, by discussing the role of the EU in managing the radio spectrum. Although the radio spectrum remains a national resource, the EU has a role to play in the way radio spectrum is used across the EU. Recognising that the EU has certain responsibilities is necessary to understand how the radio spectrum is managed. From a practical perspective, this paper provides a reach summary of EU legislative interventions in radio spectrum policy, which can be useful to policy-makers and industry practitioners that want to know more about the responsibilities of the EU in radio spectrum management.

The main limitation of this piece of work is represented by the choice to tell a narrative. When commenting on this paper, an anonymous reviewer said: "at the moment, there is (as the author notes) a narrative. We need something more forthright and convincing in order for this piece to merit publication." He or she substantially challenged the credibility of this research paper. The narrative format was chosen because it helped creating a story where there was a beginning (or past), a present and a future. The strategy adopted to reinforce the credibility of this work was to rely on the views of the critical community, in particular professional peers at international conferences and workshops, which scrutinised and questioned Paper III at different points in time. This paper remains a narrative. However, the level of details provided in the methodology section may have positively contributed to convey its quality.

4.4 Paper IV

Massaro, M. (2019) Is business lobbying in the European Union context-dependent? Evidence from the policy field of radio spectrum, *Telecommunications Policy,* in press. DOI: https://doi.org/10.1016/j.telpol.2019.101827.

Paper IV investigated contextual factors which impact on how EU business lobbying is carried out in the policy field of radio spectrum. Business lobbying has become an integral part of EU policy-making, due to transfer of legislative power from national to EU institutions. EU legislation has acquired increasing weight for a wide variety of business activities. For this reason, business interest groups regularly attempt to influence EU legislative outcomes. At the same time, EU institutions have become dependent upon the knowledge provided by external stakeholders in order to draft EU legislation.

Existing research on business lobbying distinguishes between three types of contextual factors, which relate respectively to the institutional context, the features of the policy issues discussed and the characteristics of the business interest groups. The first factor explains that business interest groups approach the Commission, the Parliament and the Council in different ways, as the EU institutions have different roles in the legislative process and, therefore, demand different types of external expertise to carry out their work. The second factor indicates that business lobbying strategies may differ depending on the degree of difficulty that the EU institutions encounter when analysing policy issues. Higher degrees of difficulty usually open up more opportunities for business interests to influence the legislative process by providing the EU institutions with their external expertise. The third factor points to the fact that, generally, larger business interest groups are more successful in exercising their influence because they have more financial, human and information resources to conduct lobbying strategies.

Qualitative data on these contextual factors was gathered by means of ten semi-structured interviews with experts directly or indirectly involved in EU business lobbying in the policy field of radio spectrum. All interviews were recorded and transcribed. Then, the interview scripts were coded in Nvivo. Based on the analysis conducted, the following conclusions were drawn: first, the Commission weighs highly information provided by business interest groups which is in line with the EU's objective to promote EU-wide coordinated use of radio spectrum. Second, the Council is lobbied both at national and at EU level. However, the way business lobbying takes place at EU level is unclear because of lack of transparency in the Council. Third, radio spectrum policy issues are characterised by a high level of complexity and generally require niche expertise to be addressed. The fact that few individuals develop such niche expertise may favour the so-called revolving door phenomenon, making regulatory capture more likely. Fourth, citizens interest representation is almost absent in radio spectrum policy. This is because of the level of technical knowledge which is necessary to understand and address radio spectrum policy issues. Lack of civil society participation can be a problem, as it may result in higher chances for legislative outcomes to favour business interests to the detriment of the interests and needs of the society at large.

Paper IV contributes to spectrum management literature, acknowledging the important relationship between decision-makers which have the authority to regulate radio spectrum use and the variety of corporate stakeholders whose businesses rely on radio spectrum access. In addition, Paper IV has implications for the more general literature on interest groups. Although centred on the EU context, the issues discussed, such as lack of transparency, regulatory capture and civil society underrepresentation, are not unique to the EU system.

The fact that "only ten expert interviews were conducted," as pinpointed by an anonymous reviewer, is the main limitation of this study. Conducting a follow-up study, with a wider sample of interviewees may be useful to enrich the conclusions of this study. In addition, Paper IV does not provide any measurement of the degree to which business interest groups influence EU legislative outcomes, whose importance has been recognised in literature on interest groups, for instance in Dür (2008).

4.5 Paper V

Massaro, M. and Beltrán, F. (2019) Will 5G lead to more spectrum sharing? Discussing recent developments of the LSA and the CBRS spectrum sharing frameworks. Under a second round of review for publication in *Telecommunications Policy*.

This paper discusses two recent spectrum management frameworks, the LSA developed in Europe and the CBRS developed in the US, which build their management approach on spectrum sharing. These two approaches were chosen because they began to be developed at the same time, in two different parts of the world, to address the common issue of finding additional radio spectrum for mobile communications services. The focus in this paper is on the potential implementation of these two sharing frameworks in the C-band, which has been identified as the primary spectrum band in the mid spectrum range (between 1 and 6 GHz) for the introduction of 5G communications networks. Both EU and US have been working on their respective sharing frameworks for a number of years. They recognised the importance of spectrum sharing to meet the growing spectrum needs of mobile communications. In addition, commercial users urged the opening of spectrum bands which are currently underutilized, mainly by government users. Based on recent work conducted by ETSI, a new version of the LSA framework is under development, called evolved LSA (eLSA). Similar to CBRS, three groups of users are envisioned under eLSA. In addition to incumbents and mobile operators, a third group of users supporting vertical industries would access the spectrum on a short-term basis and in geographically limited areas.

Paper V claims that the CBRS may have higher chances of actual implementation as compared to the LSA, notwithstanding their similarities. Both frameworks are sought to be implemented in harmonised bands allocated to the mobile service. In addition, both frameworks are technology neutral, although it is expected that the implementation of these sharing frameworks will include the use of recognised mobile standards, such as those officially approved by the ITU. This is because mobile standards are considered crucial elements to guarantee interoperability between devices and all the different parts of the mobile network infrastructure. In addition, both the LSA and the CBRS sharing frameworks include a complex scheme of usage rights and assignment procedures tailored to the characteristics of the bands considered and to the spectrum needs of the services to be deployed.

The relatively higher potential of the CBRS may suggest that implementation of spectrum sharing frameworks depends not only on their inner characteristics, but also on other aspects. An interesting aspect which deserves further attention is the regulatory powers of the entities involved in radio spectrum management. Unlike the FCC, European bodies, including the CEPT and the EU institutions, have no coercive and enforcement powers, playing a mere advisory and coordinating role when it comes to sharing approaches. Although spectrum sharing has been praised as essential for 5G, actual implementation of the LSA sharing framework in the C-band in Europe remains a national decision. In this regard, European NRAs have shown limited interests towards the LSA in

the context of 5G. In fact, several European countries have already auctioned the C-band or plan to conduct auctions in the near future.

Paper V contributes to understand the authority of the EU in radio spectrum management. The current fragmentation of national approaches to 5G bands shows the lack of regulatory power of the EU. The EU member states are free to decide whether and, if so, how spectrum should be shared within their national boundaries. The EU can propose certain approaches, as it did with LSA, but its involvement remains limited to advisory work.

At the time of writing of this introducing document, Paper V was still under revision.

5 Discussion

The aim of this section is to summarise the contribution of the five appended papers of this thesis to understand how radio spectrum is managed in the EU. This thesis addressed two research questions: what entities manage the radio spectrum in the EU? And what mechanisms are used to manage the radio spectrum in the EU? Figure 6 shows the main entities which are, to different extents, involved in radio spectrum management in the EU and four mechanisms whereby these entities operate, highlighted in different colour shades. The mechanisms are: the OLP for the adoption of EU law; the comitology mechanism for the adoption of Commission's implementing acts; the WRC process for the adoption of the RR; and the relationship between the Commission and the RSPG for the development of radio spectrum policy in the EU. They are further illustrated in the rest of this section.

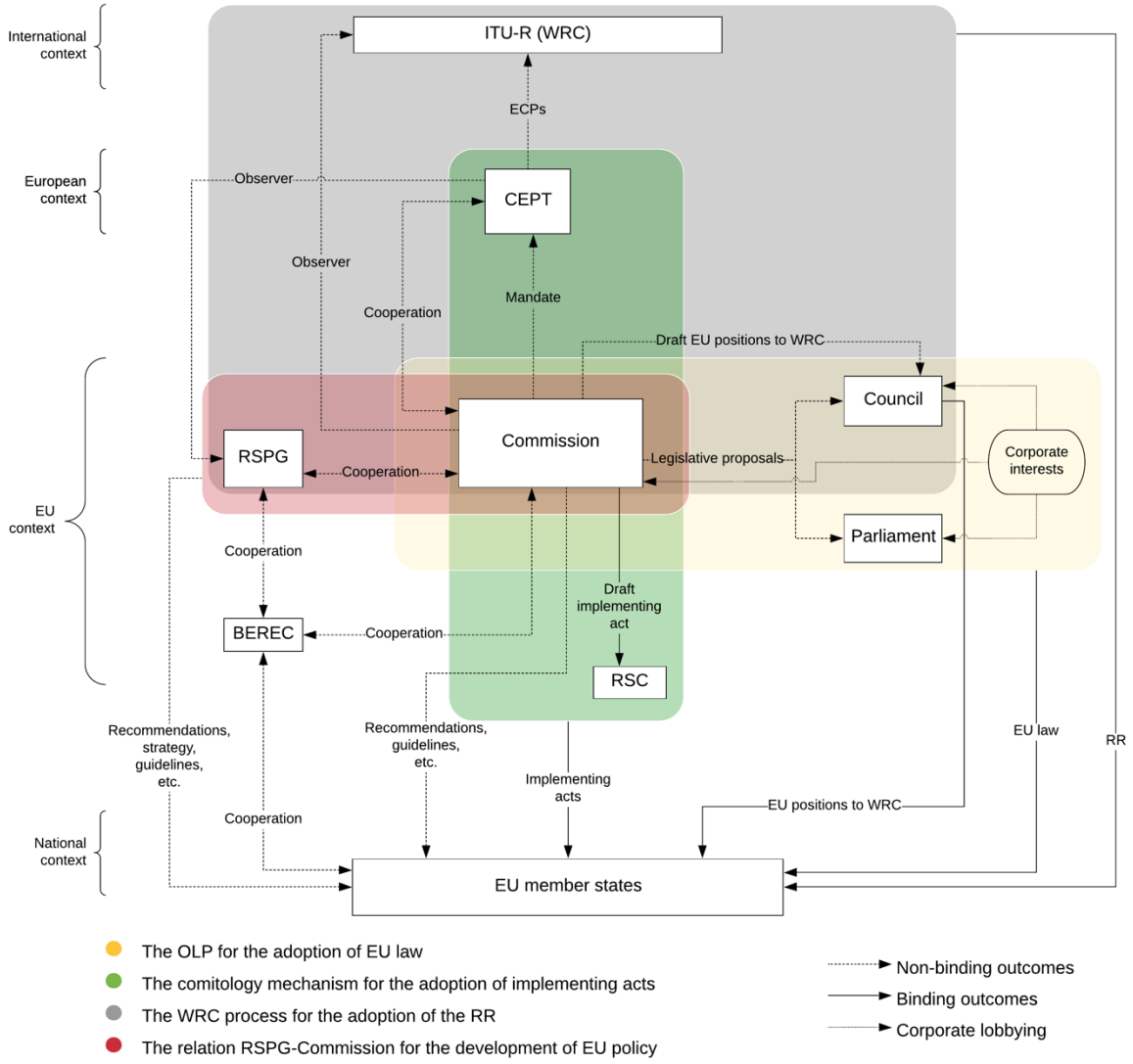

Figure 6. Entities managing the radio spectrum in the EU and relevant mechanisms

The EU's system of governance primarily relies on the adoption of EU laws via the OLP to achieve policy goals. The EU hierarchy of norms distinguishes between primary and secondary law. Primary law includes the EU treaties, general principles established by the CJEU and international agreements. The EU treaties are legally binding agreements between the EU member states. They

set out the fundamental principles and values upon which the EU is based, the institutional structure and objectives of the EU, the distribution of legislative power between the EU institutions and the EU member states, and the procedures whereby the EU institutions can adopt secondary law. Secondary law enables the EU institutions to act in various policy areas in order to pursue the interests of the EU, within the limit set by the EU Treaties. Secondary law is generally distinguished between legislative acts and non-legislative acts. Legislative acts are generally adopted by following the OLP, whereby legislative proposals formulated by the Commission are jointly decided upon by the Parliament and the Council. Non-legislative acts are called delegated and implementing acts and are enacted by the Commission. These acts are labelled as non-legislative because their function is to support the correct implementation of EU law across the EU. Nevertheless, their content is legally binding.

The EU began to adopt EU laws in radio spectrum policy in the late 1980s, as soon as it became clear that coordinated radio spectrum use across the EU was beneficial for the creation of the EU internal market for telecommunications. Since then, revisions of the EU policy and legislative framework have taken place every ten years, triggered by the emergence of new generations of mobile cellular technologies and of the increase of commercial services, which demanded access to the radio spectrum. The interaction between corporate stakeholders and the EU institutions is an integral part of EU decision-making. The EU institutions and business interests depend on one another, the former generally lacking the market expertise of corporate stakeholders to make decisions, the former aiming to shape EU legislative outcomes to safeguard their business interests. Over time, expansion of the topics covered by EU law determined transfers to EU institutions of certain responsibilities concerning radio spectrum use in the EU. Nevertheless, the EU member states have constantly opposed major limitations of national sovereignty.

Although EU law is generally co-enacted by the Council and the Parliament, a substantial body of rules is actually adopted by the Commission acting alone, with extensive resort to the comitology process for implementing acts. Such process usually takes place in three steps. First, the Commission places a mandate to the CEPT to conduct technical studies, generally on issues related to harmonised radio spectrum use across the EU. Second, the Commission formulates technical measures, based on the results of the studies conducted by the CEPT. Third, such measures are included in Commission's implementing acts, which are discussed and voted by the Radio Spectrum Committee (RSC). Created in 2002 by a decision of the Parliament and the Council, the RSC is composed of representatives of the EU member states (Parliament and Council 2002). Commission's implementing acts require the approval of the RSC, acting on a qualified majority voting. The comitology process involving the Commission and the RSC is the primary instrument for radio spectrum harmonisation across the EU.

With regard to the WRC process, the EU Treaties, in particular the TEU and the TFEU, require the EU member states to comply with certain principles when representing their interests at international level. For instance, article 4 of the TEU states that the EU member states "shall facilitate the achievement of the Union's tasks and refrain from any measure which could jeopardise the attainment of the Union's objectives" (EU, 2012). The EU member states and the EU institutions are subject to a duty of sincere cooperation, which is a mutual legal obligation to closely cooperate in order not to harm the proper functioning of the EU. Furthermore, the EU member states have the legal obligation to cooperate so as to guarantee a united representation at international level of the EU's objectives, as clarified by case law of the CJEU (CJEU, 2007).

The EU also adopts a so-called EU position to ensure that the EU member states coordinate at WRC. The EU position sets out the EU objectives with respect to the issues included in the WRC agenda to be decided upon during the WRC. The EU member states are legally bound to the EU position,

which is drafted by the Commission and ratified by the Council in the form of a decision, which is legally-binding. The Council acts on a qualified majority voting, once obtained the consent of the Parliament. In addition, the Commission legally represents the EU in the context of the ITU. The Commission carries out different functions, including attending the WRC as observer. Although without formal vote, the EU provides the EU member states with guidance on EU priorities related to WRC issues (RSPG, 2017). Moreover, the Commission gives input to the CEPT during the preparatory work to the WRC.

The work of the CEPT and the EU is largely intertwined in radio spectrum management, although the CEPT has a larger scope of action than the EU, representing a broader geographical area than the twenty-eight EU member states. The Commission and the CEPT collaborate in the context of the WRC, jointly organising workshops to inform all relevant stakeholders about the EU objectives with respect to the items included in the WRC agenda. In addition, the CEPT and the Commission have legally set forth their intent to cooperate in a memorandum of understanding. On the basis of this memorandum of understanding, the Commission issues the CEPT with mandates to carry out technical studies in the context of the comitology process involving the RSC (Commission and CEPT, 2004). Moreover, the Commission takes part in the activities of the CEPT as an advisory body, with the right to speak, but not to vote.

Due to national resistance to transfer of decisional power, the EU implements also soft instruments to achieve policy objectives. A main objective in radio spectrum policy is the removal of certain national differences in management practices. The process of "integrating by law" has always been characterised by a tension between transfer of legislative power to EU institutions and protection of national sovereignty. This tension increases as the EU tries to extend its scope of action to issues traditionally considered by the EU member states of exclusive domestic domain. In radio spectrum management, aspects such as the assignment of authorisations for the use of radio spectrum is strictly considered a national responsibility. Soft mechanisms put in place by the EU include exchange of information, recommendations, resolutions, and opinions, as well as mechanisms of review and monitoring, benchmarking and peer reviewing. The EU seeks to encourage the EU member states to pool information together, compare themselves to one another, and periodically assess their performances relative to desired goals.

In an attempt to strengthen cooperation between the EU member states, the RSPG was recently granted new tasks. Established in 2002 by the Commission as an advisory body, the remit of the RSPG has been extended as a result of the adoption of the European Electronic Communications Code in 2018 (Parliament and Council, 2018a, Commission, 2019). The RSPG adopts opinions, publishes positions papers and reports, and organises workshops and public consultations, to discuss radio spectrum policy issues with relevant stakeholders. Among its various tasks, the RSPG assists the Commission for the formulation of common policy objectives in preparation of the WRC; it formulates opinions on Commission's legislative proposals and recommendations on EU policy objectives. In particular, the RSPG contributed to the conceptual development of different approaches to radio spectrum sharing, which are part of the EU policy and legislative framework, publishing opinions and reports on CUS and LSA.

In addition to the advisory work carried out for the Commission, the RSPG can also assist the Council and the Parliament, if requested. Nevertheless, neither the Council nor the Parliament seem to have made use of the RSPG's services, according to the data gathered. Moreover, the RSPG collaborates with other relevant entities for radio spectrum management in the EU, such as the CEPT at European level and BEREC in the EU context (BEREC and RSPG, 2019). The role of BEREC was also reinforced as a result of the adoption of the European Electronic Communications Code in 2018

(Parliament and Council, 2018a, 2018b). The BEREC figures as an intermediary actor between the Commission and the NRAs, offering the latter a context to interact and exchange ideas. Although without formal legal and enforcement powers, the RSPG and the BEREC are expected to contribute to a harmonised regulatory environment across the EU member states.

The EU and the EU member states share the responsibility to manage the radio spectrum. The EU pursues the goal of harmonizing radio spectrum management and use across the EU, removing differences in the way the radio spectrum is managed and used nationally. The EU considers EU-wide coordinated use of radio spectrum as an essential condition for the well-functioning of the internal market for telecommunications. At the same time, the EU member states oppose centralization of power at the EU level, questioning the benefits of a fully-fledged EU coordinated approach to radio spectrum. As a result of this tension between the aim of the EU to drive EU integration further and the opposition of the EU member states to restriction to their national sovereignty, there is no clear-cut division of competences between the EU and the EU member states. As shown in Figure 7, the EU member states manage the radio spectrum in their respective national territories. In addition, the EU member states are involved in the development of a coordinated approach to radio spectrum management, national representatives being involved in the work of supranational entities, at EU, European and international level. Each EU member state decides on the size and composition of its national delegation to the various entities (e.g. Commission 2002; 2011). Whether and to what extent the different national delegations are committed to creating a pan-EU approach to radio spectrum remains an open question.

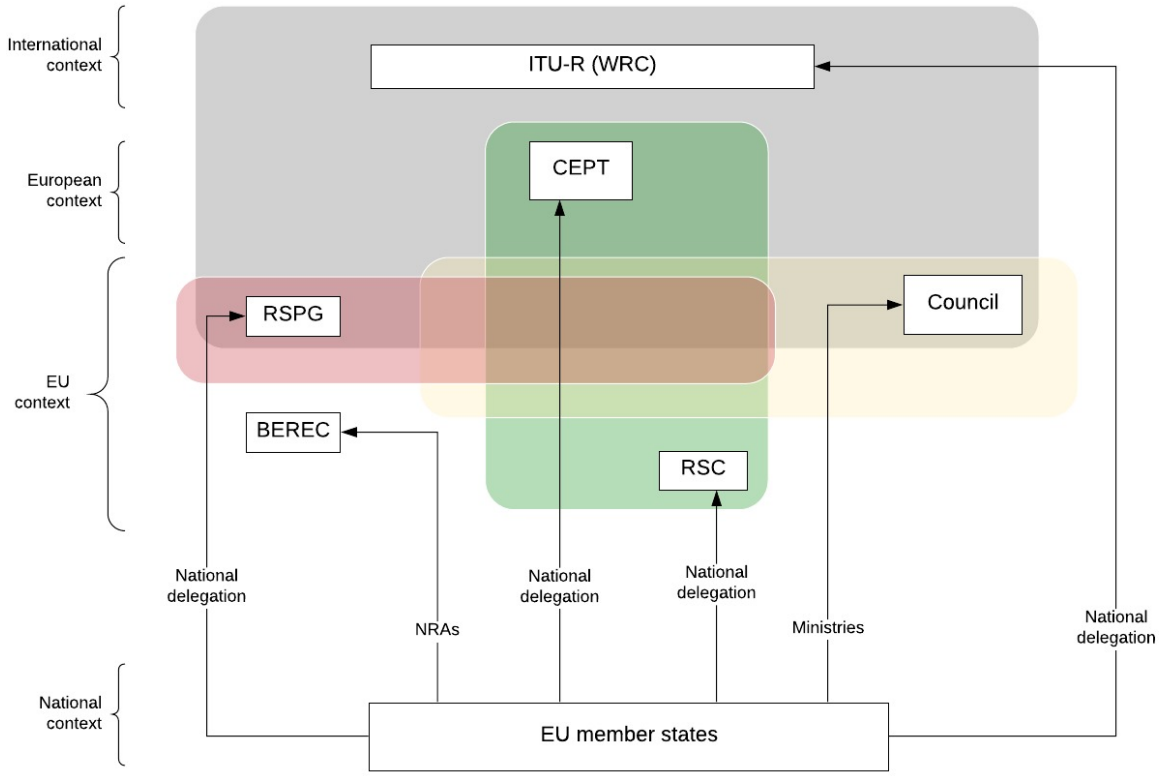

Figure 7. National representatives to EU, European and international entities

Radio spectrum management in the EU is the result of the work of a variety of supranational and national entities. Over time, the EU has gradually developed a systematic approach to radio spectrum management, designing various mechanisms to promote EU-wide coordinated radio spectrum use

across the EU. The use of legally binding acts has been essential to remove certain differences in national management practices. At the same time, there are areas of radio spectrum management where the EU plays a mere advisory role, while relevant decisions are taken by the EU member states. This is particularly true for radio spectrum assignment. Technological progress has often motivated the EU to put pressure on the EU member states for further integration. In this regard, it can be expected that future technological changes will motivate the EU to prompt further changes in the distribution of responsibilities between the two levels of governance.

6 Future research

This thesis drew on theoretical insights from four research domains to explain radio spectrum management in the EU. A set of entities that collectively manage the spectrum resource in the EU and key mechanisms whereby these entities operate, were identified. This work shows that there is separation between these entities, in terms of their roles and responsibilities in the identified mechanisms. Nevertheless, their interaction reveals the complex, dynamic and often fraught nature of the relationship between the EU and its member states.

Over time, the EU has developed a more systematic approach to radio spectrum management, formulating legally binding tools in the effort to establish an EU-coordinated approach to radio spectrum use across the EU. At the same time, there are certain areas of radio spectrum management where the EU plays a mere advisory and coordinating role, while relevant decisions are taken at national level. It is hardly possible to talk about a clear-cut division of powers between the EU and its member states. This is because of the dynamic nature of the shift in responsibilities between the two levels of governance, which is inherent of a political system taking shape.

This thesis work may have given rise to a number of questions about how the radio spectrum is managed in the EU. In fact, the reader is encouraged to consider this thesis as a starting point, hinting to several research paths to be explored in the future. Two potential research paths are presented here below. The former follows the research approach used in this thesis, where ideas are borrowed from four research traditions to understand radio spectrum management in the EU. The latter proposes to broaden the range of possible literatures to be used to describe and analyse radio spectrum management.

6.1 Continuing this research work

This research work started with digging into EU integration literature to study the distribution of legislative power between the EU and the EU member states in radio spectrum policy. A clear aspect of radio spectrum management in the EU, which emerged from this work, was the leading role of the Commission in the development of a common approach to radio spectrum across the EU. In particular, a lot of detailed rules regarding radio spectrum use in the EU are set by the Commission in the form of implementing acts. The EU member states have largely criticised legally-binding acts enacted by the Commission alone because of lack of legitimacy. The problem of legitimacy would stem from the fact that the EU member states lack adequate mechanisms to monitor the exercise of executive power by the Commission. In particular, the scrutiny operated by the EU member states organised in committees appears to be insufficient. Empirical research on comitology procedures suggests that the committees may not have the expertise to decide on the issues at stake and, therefore, they would tend to support the Commission's proposals (Voermans et al., 2014). Lack of transparency is another aspect which contributes to the criticisms against the executive power of the Commission and comitology. Committees generally work behind closed doors, limiting the possibility for other EU institutions to be involved, in particular for the Parliament to exercise its supervisory and control powers. Considering the prominent role that the comitology process plays for radio spectrum management in the EU, lack of legitimacy of the Commission is an issue which requires further investigation. The question is whether the RSC functions as control mechanism over the executive power exercised by the Commission or whether the Commission benefits from large room of manoeuvre, to an extent that justifies the criticisms regarding lack of legitimacy.

A main limitation of this research is that the EU member states were considered as a single group, disregarding their differences in managing and using the radio spectrum. A concept which is often associated to the EU is the concept of "multi-speed Europe," also known as "differentiated integration." These terms are used to describe the varying degrees of participation of the EU member states to the EU-building process due to great diversity in political, economic and institutional settings (Dyson and Sepos, 2010). The institutional set-up may impact on the way the radio spectrum is managed nationally. In the EU member states, the responsibility of managing the radio spectrum is distributed to the NRA and to one or several government ministries to different extents. The national political and economic situation may also impact on the way the radio spectrum is managed and used nationally. Countries may differ in terms of amount of financial and human resources which can be invested in radio spectrum management, larger amounts of resources usually suggesting better ability to understand and manage the radio spectrum. In addition, certain public or private services may find better support in governmental decisions because in line with national interests. Studies with a national focus could be conducted for better understanding how the radio spectrum is managed in the EU. For instance, identifying relevant differences in political, economic and institutional settings between the EU member states may help explain varying national responses to EU legislative interventions.

During this research process, it appeared relevant looking into the international relations literature to understand the participation of the EU in WRCs, where radio spectrum issues are discussed and decided upon internationally. Nevertheless, the nature of the EU as global actor remains largely unexplored. In particular, understanding the role of the EU as a global actor in the ITU would require assessing the capability of the EU to gain support of its member states (Jørgensen et al., 2011). Although the EU member states are, to some extent, legally obliged to cooperate, there seems to be large room of manoeuvre for individual countries at the international stage. Internal coordination is necessary to ensure that the EU member states support the interests of the EU at international level, in particular when the EU is not recognised full membership by international organisations. In this regard, exploring whether and to what extent the EU member states support the involvement of the EU in the work of the ITU may contribute to a better understanding of the international role of the EU. The institution which represents the EU in the ITU may also have an impact on the relevance of the EU to its member states. The EU external representation in the ITU is currently exercised by the Commission. It may be worth investigating whether the EU external representation should be exercised by the Commission alone or whether other EU institutions and bodies, and if so, which ones, may play a role.

Although touched upon in this research work, the phenomenon of interest representation in radio spectrum policy deserves a closer investigation. As the radio spectrum is essentially a national responsibility, lobbying in the Council appears to be an interesting area of investigation. In comparison to the Commission and the Parliament, less research has been focusing on the Council, mostly because of lack of transparency of its internal mechanisms, the Council generally adopting a behind closed doors approach to decision-making. Increasing levels of transparency may result from the extension of the so-called Transparency Register to the Council.[4] The Transparency Register is a public website which contains information about entities representing particular interests at EU level. Currently, corporate representatives are expected to register in order to be able to interact with

[4] Official website of the EU Transparency Register, https://ec.europa.eu/transparencyregister/public/homePage.do

the Commission or the Parliament. Extending the Transparency Register to the Council would provide public access to additional data for investigating the phenomenon of lobbying. For instance, it may be interesting to look at whether there is variation in lobbying activities based on the Council presidency, which rotates among the EU member states every six months. In addition, this thesis looked at how companies and business interest representatives seek to influence the EU institutions. However, other perspectives could be taken to better understand the phenomenon of lobbying in the EU. In particular, the interaction between the EU and national institutions is a fertile area of future research. Studies may be conducted to investigate whether the EU interacts with companies who support EU objectives to exercise pressure on national governments which oppose centralisation of decisional power.

Another interesting aspect which deserves to be investigated is the involvement of civil society in radio spectrum policy. On the basis of this research work, it can be claimed that civil society representation is largely absent in radio spectrum policy. This is probably due to the technical expertise required to comprehend the issues discussed, which the civil society most likely lacks. Participation of civil society in public policy-making is an integral part of democratic systems. In this regard, it may be interesting to assess the value of the participation of civil society in discussions on radio spectrum use and the tools the EU may utilise to inform and encourage civil society participation.

6.2 Beyond this research work

This research work was thought to be multidisciplinary and international in scope. It was intended to serve a readership of researchers, policy makers and industry practitioners who are interested in both radio spectrum management and the functioning of the EU. The ambition was to position this research somewhere between radio spectrum management studies and political science studies, addressing political and institutional aspects of the EU system. Nevertheless, balancing the amount of details and making sure that this research could contribute to both research streams have been challenging tasks. Technical experts may claim that this work "is merely an analysis of the EU approach [to radio spectrum management], but it does not contribute to the discussion of [for instance] 5G," as suggested by an anonymous reviewer of a peer-reviewed journal in the ICT domain. At the same time, EU scholars may criticise this work for being "too specific on technical issues […] and too basic on EU affairs," as argued by an editor of a peer-reviewed journal publishing EU studies.

The attempt to publish parts of this work in journals dedicated to EU studies was unsuccessful and the five appended research papers were sent to, and some of them successfully published in, multidisciplinary journals which address, from different angles, aspects of the ICT sector. In order to target other types of journals which publish research work on EU issues, or broader political science issues, a deeper understanding of their traditions and debates is required. Time could be spent to gain familiarity with EU integration, international relations and lobbying literatures, as well as, other literatures to shape research on radio spectrum management so as to send relevant messages to journals outside the ICT domain.

A concept which originated from studies on EU integration and became popular among political science scholars is that of multi-level governance. The concept of multi-level governance is used to describe the reallocation of authority "away from central government—upwards to the supranational level, downwards to subnational jurisdictions, and sideways to public/private networks" (Hooghe and Marks, 2001: 3). EU integration, international relations, public administration and federalism literatures are among those which have sought to address the core issue of how decision-making

power should be distributed to different levels of governance. In this regard, radio spectrum management appears to be an interesting case to be analysed, decisions on radio spectrum use being taken at different levels of governance.

The WRC process represents a relevant place where it can be observed how decision-making power is allocated to and exercised by various public and private entities. For instance, national delegations attending WRCs are entitled to a single vote when deciding on amendments to the RR. Nevertheless, decisions are generally taken by consensus, the voting procedure considered complex and limited to exceptional circumstances. During negotiations, coalitions between countries play an important role, ITU members grouping together to get a position before negotiating at WRCs. In addition, it is commonplace that national delegations representing their respective countries at WRCs are composed by representatives not only from national governments, but also from NRAs and, most importantly, companies. Entities from the private sector are ITU sector members, with the right to participate in the preparatory process to WRCs and to attend WRCs as observers. Moreover, being part of national delegations give them the opportunity to directly influence the decision-making process at WRCs. Therefore, investigating how public and private interests interact at international level appears to be a potential fruitful area of research. Overall, this thesis lays the groundwork for exploring radio spectrum management in a political science context. Since radio spectrum management as an area of research has been largely overlooked, there is strong potential to broaden the appeal of it to non-ICT disciplines.

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